OXY-ACETYLENE WELDING AND CUTTING

SWINGLE

Oxy-Acetylene Welding and Cutting

Including

The Operation and Care of Acetylene Generating Plants

And

The Oxygen Process for Removal of Carbon

By

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PREFACE

The Oxy-acetylene flame is now used to advantage in welding practically all metals, as steel, cast iron, malleable iron, brass, bronze, copper, aluminum, sheet iron and silver. Its success has been proved beyond a doubt. Engine and machine parts of any metal, automobile castings and the like are as strong as any part of like dimensions when welded.

A brief description of all principal kinds of welding is given, including fire welding, welding by water gas, thermit welding, brazing and blowpipe welding. The advantages and disadvantages of each are discussed.

Manufacturers, contractors, machine shops, garages, blacksmiths, boiler makers, repair shops, foundries, steel mills and railroad shops are rapidly adding the oxy-acetylene process to their equipment. In cutting beams, girders, steel sheeting, heavy piston rods, steel plates, gates from steel castings, wrecking steel building frames or bridges, the work can be done much cheaper and in less time than by the old methods.

In the preparation of this book the author has endeavored to cover every practical point in the process of welding and cutting and the removal of carbon with oxygen. Enough of the theory has been included to enable the practical man to acquire a thorough understanding of the subject.

Reference to the table of contents on the following pages will show the scope of the book. Numerous illustrations of distinct advantage to the operator have been included.

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OXY-ACETYLENE WELDING AND CUTTING

CHAPTER I

WELDING

The fusion or welding of metals is accomplished by an intense heat concentrated at the location of the weld. The temperature of the oxy-acetylene flame taken at the extremity of the white jet has been calculated to be 4000° Centigrade, or 7232° Fahrenheit. In practice a temperature of approximately 6500° Fahr. is obtained by means of the oxy-acetylene process, and this temperature is more than sufficient to melt any of the commercial metals. By the application of this temperature the metal at the point of treatment is rapidly reduced to a liquid molten state, flowing together and thoroughly mixing with a proper quantity of metal added by the operator to fill up all the crevices. The fluid mass thus formed does not result in merely cementing the two pieces of metal together; it fuses them into one piece.

VARIOUS METHODS OF WELDING

In order to appreciate the advantages of oxy-acetylene welding as compared with other methods it is well to consider, briefly, the leading methods of unit-

ing pieces of metal by the weld, most of which are still used to some extent.

Welding at the Forge.—This method has been known from the most remote time. Its application, however, is practically limited to iron and steel. A joint is obtained by energetic hammering together of the two pieces of metal which have been previously brought to a welding heat in the furnace or forge fire. The important points connected with this method consist in the ability to recognize the welding heat and to avoid burning the metal by going beyond this point, and the difficulty of so joining the metal pieces that the weld is perfect over the entire surfaces that are to be joined. Metals can only be welded between certain exact limits of temperature, and it requires skill and experience to be able to know these temperatures.

The success of a fire weld depends on the exact external observation of temperature and the state of the surfaces to be united, because all interposition of slag or oxide hinders complete welding.

It is therefore necessary to sprinkle the surfaces to be welded with a flux capable of dissolving the oxide of iron and to form with it an extremely fluid compound which can be expelled by hammering. As for the brazing of iron, the materials used for fire welding are generally white sand and borax. Certain special materials, of satisfactory composition and easy use, are sold and give excellent results.

Fire welding has the following disadvantages:—

(1) It is necessary to heat a large portion of the articles to be united and this causes deformation, hence the necessity for considerable working of the metal after welding.

(2) Large quantity of heat wasted, rendering the process costly.

(3) Difficulty of insuring uniform success and impossibility of exact control.

Forge welding is done, where possible, by joining the two sections after the edges or ends have been beveled, known as a scarf weld. This increases the surface in contact and the strength of the joint. The strength of these welds very seldom exceeds 70 per cent of the original strength of the metal.

The enlongation of forge welds is always very low, that is, the portion welded will break apart before stretching to any extent under strain. From the point of view of brittleness, forge welds show a very low average of results, and frequently in tests under shock, separation takes place at the weld. The results obtained are notably inferior to those obtained with well-executed oxy-acetylene welds.

Welding by Water Gas.—This constitutes a more perfect form of forge or fire weld. Instead of raising the edges to be joined to a welding heat by fire, they are submitted to the action of a blowpipe fed by water gas. This gas is chosen because it can be produced on the spot very economically. It is made by passing steam over red-hot coke, and consists of carbon monoxide and hydrogen, which produce a very high temperature by their combustion. Pneumatic tools rapidly hammer the two edges of the weld when they have been raised to a welding heat by the flame.

Welding by water gas necessitates a very costly installation, and does not pay unless it is used continuously on a very large scale. It is not practically applicable unless the plates have a thickness of at least $\frac{5}{16}$ inch.

Thermit Welding.—This process is only applicable to the joining of iron and mild steels of considerable thickness. It consists essentially in burning in a crucible a mixture of powdered aluminum and iron oxide. The temperature of combustion is excessively high, and can attain 3000° C. (or over 5400°F.). The aluminum unites with the oxygen to form alumina, while the iron which is set free accumulates in a molten state at the bottom of the crucible.

This is made to flow, by the aid of a suitable mould, round the parts to be joined, and its temperature is high enough to melt the edges to be joined; thus a weld which might be called autogenous is obtained.

It will be understood that the process, which requires costly material, can only be used for important or repetition work. It has chiefly been used for the welding of rails and the repair of very large steel castings. Oxy-acetylene welding is largely replacing it.

Brazing.—Brazing is accomplished by the use of a metallic cement, melting at a high temperature and possessing a high mechanical strength. Given these facts, one can see that it is necessary to heat strongly the edges to be joined and to use a cleaning flux melting at a high temperature.

The metallic cement used is called brazing metal, and can be applied in the form of a powder, paste, filings, or grains often mixed with the flux. Its melting point is just below that of the metal to be joined, so that in heating the pieces to be brazed, the brazing metal melts and adheres to the edges to be joined when they reach a high temperature, thus even forming an intermediate alloy, and the joining is obtained simply by cooling.

When it is a question of joining end to end or edge

to edge, the brazing is done with bevelled faces placed side by side. It is clear that this increase of surface in contact increases the resistance of the joint.

Brazing necessitates the use of a forge or blowpipe. The use of a forge is costly, inconvenient, and cannot be applied to articles of all brass composition owing to liability of burning the metal. However the use of blowpipes giving high temperatures, oxy-acetylene for example, makes possible the use of brazing metals that are less fusible; for instance, red copper in joining pieces of cast iron. Brazing seldom fulfills the conditions required for perfect joining of metal pieces. The following are the principal disadvantages pertaining to brazing:

(1) The part brazed possesses a different color to that of the metal.

(2) This same portion has different chemical, physical and mechanical properties from the other metal and may, little by little, disintegrate.

TABLE I

COMPOSITION AND APPLICATION OF BRAZING METALS

Application.	Composition.				
	Copper.	Zinc.	Malleable Brass.	Silver.	Gold.
For copper, brass, iron....	2	1	5	..	..
For copper, brass, iron....	..	1	..	..	..
For copper (very fusible)..	50	48	..	2	..
For turning brass.........	45	45	10	10	..
For brass	1.5	6	1	..	..
For steel	1	..	1	19	..
For plates	..	..	1	2	..
For copper or iron........	..	..	1	1	..
Fusible solder	..	1	..	5	..
For silver (950 parts in 1000)	23	10	..	67	..
For gold	1	..	..	..	5
For gold (750 parts in 1000)	1	..	..	1	4

Blowpipe Welding.—Blowpipe welding consists in uniting the metal pieces by means of a flame of appropriate temperature with the addition of metal of the same composition. The joint thus obtained is called autogenous.

Strictly speaking, the welds obtained by the fire, water gas, or electricity can be called autogenous, since they have been obtained without the interposition of a metallic cement whose properties differ from that of the metal joined.

In current language the name autogenous welds is understood to mean those which are obtained by melting the metal under the action of the flame of a blowpipe.

The blowpipe is an instrument in which the flame is produced and projected on to the metallic parts to be welded.

Blowpipe welding has been known for a long time, at least for the joining of metals whose melting-point is not very high, and was easily obtained by combustible gases burning in air or in a current of air. The autogenous welding of lead was thus obtained by the Egyptians, the Greeks, and the Romans.

The autogenous welding of metals with high melting-points was not possible until the industrial manufacture of oxygen permitted the use of this gas for the production of flames of high temperature.

First of all the oxy-hydrogen (oxygen and hydrogen) flame, then the oxy-acetylene (oxygen and acetylene) were thought of. After these oxy-coal gas (oxygen and coal-gas), oxy-benzene or oxy-benz (oxygen and vapour of benzol), etc.

Autogenous welding by means of the blowpipe is the process that has been most developed in recent

years. This is proved by its use in the majority of work shops for construction and repairs. The one defect in connection with blowpipe welding is that, owing to the apparent ease with which the work is done, it is, in many cases, applied by persons who have made no previous study of its requirements. Proper care is not used in the work and the result is many failures.

Welding at the forge, brazing, or even soldering, all require special knowledge on the part of the operator in order that he may be able to do reliable work. The easy appearance of blowpipe welding often leads an unskilled workman to attempt to do a job which, while often appearing perfect on the outside, is defective and unsafe.

ADAPTABILITY OF VARIOUS SYSTEMS OF BLOWPIPE WELDING

The manufacturer or workman who wishes to apply autogenous welding should study the various systems which are offered, and find which gives him the most advantages.

The principal points to which he should direct his attention are the following:—Adapting the System to the Type of Work; Safety; Quality of Work; Economy; Convenience; Cost of Material.

Adapting the System to the Type of Work.—When a process is no longer applicable to the work under consideration all interest in the process lapses. In reality, the value or economy of any particular system of blowpipe welding depends upon the type of work. Among the processes enumerated, it is first of all necessary to discern which is best applicable to the type of work.

Safety.—It can be considered that all the processes of blowpipe welding have been sufficiently studied and developed as not to offer any serious danger if the usual precautions are observed. The systems using benzol or other combustible liquids have become safe, and are practically free from danger.

Quality of Work.—The quality of the work produced by blowpipe welding is not the same in all systems. According to the metal and its thickness, the weld may be more or less well finished and sound, and a process which may be satisfactory in one case may not prove so in another. It is therefore necessary th each system should be kept in its particular sphere usefulness.

Economy.—The factor of economy may differ according to the application of autogenous welding contemplated. In certain cases the cost of the work of first importance, while in other cases this may be a secondary consideration. A certain process appear to be economical and yet be expensive, or economical under certain conditions or for certain welds and not for others. The question of the net cost of welding must be considered with reference to the quality of work and convenience.

Convenience.—Convenient application is important in the choice of a method and should be carefully studied from all points of view, such as installation, maintenance, supervision, etc. A system which seem to offer great simplicity and convenience may not prove so in practice. Good judgment is therefore necessary, followed by a comparison of the different methods with reference to the kinds of work to be done.

Cost of Material.—The various systems of blowpipe

welding do not have the same purpose in view, and the importance that is attached to some of them is only on account of the facility and economy of their installation. They may be applicable where others are not, and it is only from this point of view that they deserve attention.

On the other hand when it is a question of regular or important work, the question of first costs will not be so important, the extra cost of material being soon recovered owing to more economical working, greater convenience and better results.

CHAPTER II

WELDING FLAMES

OXY-ACETYLENE FLAME

Although oxy-hydrogen welding was proposed before oxy-acetylene, the latter process is by far the most common and will therefore serve as a basis for comparison with others. The first blowpipes working with acetylene under pressure were made in 1901 by MM. Fouché and Picard. From 1903 it has been applied industrially, and the progress has been extremely rapid.

In 1895 M. Le Chatelier, in a paper read before the Académie des Sciences on the temperature of flames, stated that "acetylene burnt with an equal volume of oxygen gives a temperature which is 1832° Fahr. higher than the oxy-hydrogen flame. The products of the combustion are carbon monoxide and hydrogen, which are reducing agents"; and the paper concluded with this sentence: "This double property makes the use of acetylene in blowpipes of very great value for the production of high temperatures in the laboratory."

As was first pointed out by M. Chatelier, the oxy-acetylene flame results from the combustion of a mixture of oxygen and acetylene in equal volumes. Theoretically it requires 2½ volumes of oxygen to completely burn 1 volume of acetylene, and this is actually what takes place if one takes into account the oxygen taken from the air during the last phase of the combustion; but the blowpipe need only supply the oxygen

necessary to form the white welding jet, and for this the volume is exactly 1 to 1.

In practice, however, the volumes are in the ratio of 1.28 to 1.13 of oxygen for 1 of acetylene, owing to the fact that the mixture of the two gases is not absolutely perfect. Below are given the chemical formulæ and equations representing oxy-acetylene combustion.

Burnt with an equal volume of oxygen, acetylene produces hydrogen and carbon monoxide:—

$$C_2H_2 + 2O = H_2 + 2CO.$$

Acetylene and oxygen yield hydrogen and carbon monoxide.

The hydrogen and oxide next burn, taking the necessary oxygen from the air and producing water vapor and carbon dioxide:—

$$CO + O = CO_2.$$

Carbon monoxide and oxygen yield carbon dioxide.

$$H_2 + O = H_2O.$$

Hydrogen and oxygen yield water vapor.

The carbon monoxide formed in the first part of the combustion is therefore entirely burnt in the second, and it could not be otherwise unless one deprived the flame of air. A paper by M. Mauricheau-Beaupré to the Académie des Sciences in January 1906 describes a series of tests which point to the complete absence of carbon monoxide in the atmosphere surrounding the oxy-acetylene flame. Poisoning of welders has therefore never existed other than in the imagination of manufacturers of blowpipes for gases other than acetylene.

The combustion of 1 cubic foot of acetylene produces 410 calories, or 1630 British Thermal Units, nearly five times as much as that of hydrogen and three times as much as oil gas. Of these, 68 calories,

or 270 B.T.U., are due to the heat of dissociation of the acetylene, which is an endothermic gas, and disengaging suddenly at the moment of its decomposition, explains the very high temperature at the beginning of the flame. It should be noted that the other gases which are used in autogenous welding do not possess this property.

Temperature.—The temperature of the oxy-acetylene flame, taken at the extremity of the white jet is very much higher than that of any other flame. It is estimated to equal 6500° Fahr. The white jet of this flame will in cases melt lime, the melting point of

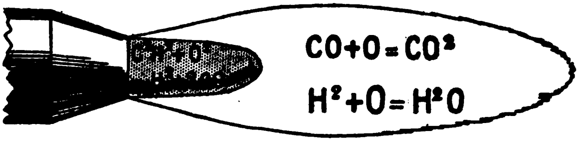

Figure 1.—Phases of the Combustion in the Oxy-acetylene Flame

which is 5400° Fahr., and this can only be obtained otherwise in the electric arc.

Combustion.—The final products of combustion are carbon dioxide and water vapor, the latter in less quantity than for the oxy-hydrogen flame, but the molten metal, under the action of the flame only comes in contact with the carbon monoxide and hydrogen produced in the first stage of combustion, since the welding is done at the extremity of the white jet.

These gases, which have the property of taking care of any excessive oxygen and avoiding burnt metal, form a flame, which when properly proportioned, have but little effect on the characteristics of the metal. This flame is said to be neutral. Figure 1 shows in a

graphic manner the phases of combustion in the oxy-acetylene flame.

Utilization of the Heat.—The coefficient of utilization is very high in the case of the oxy-acetylene flame because the highest temperature is concentrated at the point of the welding flame, the white jet.

Regulation.—The regulation of the blowpipe is accomplished with the greatest ease, and neither their working nor their manufacture offers any difficulties. They are constructed for all deliveries from 1¾ to 140 cubic feet of acetylene gas per hour, and in all well designed installations absolute safety is assured.

OXY-HYDROGEN FLAME

The first oxy-hydrogen blowpipe appears to have been suggested by Robert Hare of Philadelphia about the year 1805. In 1820 Brooke, in Germany, designed an arrangement by which a mixture of oxygen and hydrogen, previously compressed by means of a force-pump into a strong plate vessel, escaped by a capillary tube of glass. When the extremity of this tube melted or became stopped up, it was only necessary to break off a small portion to set it in working order again.

This type of blowpipe, the manipulation of which was dangerous because of pre-mixing of the two gases, was first modified by Berzelius. Next Pius Sainte-Claire Deville made a blowpipe, using oxygen and hydrogen compressed in two separate vessels. He succeeded in melting iron, silver, and platinum.

The oxy-hydrogen blowpipe remained a laboratory instrument until such time as the gases could be produced at a low price and arrangements devised for their safe storage.

It was first introduced for industrial autogenous

welding in 1901. The oxy-hydrogen flame is produced by the combination of two volumes of hydrogen with one volume of oxygen, forming water vapor. The chemical expression follows:

$$H_2 + O = H_2O.$$

Hydrogen and Oxygen yield Water Vapor.

In the first applications to autogenous welding it was found that the water vapor which is produced exclusively and abundantly, provoked considerable oxidation of the metal when raised to melting point or simply heated, and that all serious joining was impossible. The only artifice possible was to dilute the water vapor with an excess of hydrogen, and in order to produce good welds, it was necessary to raise the proportion of the gases from 2 to 4 volumes of hydrogen, for 1 volume of oxygen, and this is what has been done in practical applications.

The oxy-hydrogen flame used in autogenous welding results from the combustion of a mixture of 4 volumes of hydrogen and 1 of oxygen, half the hydrogen used serving to dilute the water vapor formed at the beginning of the reaction, then burning afterwards in oxygen borrowed from the air.

It is understood that in spite of the artifice of using excess hydrogen, the disadvantage of oxidation of the metal by the water vapor still exists in part, because diluting this water vapor does not get rid of it. The metal, during welding, heated or melted, is always therefore in contact with an atmosphere which is less neutral than in the case of acetylene.

One cubic foot of hydrogen produces 88 calories, equal to 350 British thermal units (abbreviated B.T.U.). One cubic foot of acetylene produces 410 calories, equal to 1630 B.T.U.

Temperature.—For the same number of heat units, the oxy-hydrogen flame is less in volume than the oxy-acetylene flame, the heat is less easily utilized for obtaining autogenous welds owing to the fact that the high temperature zone is not so well localized. Neither is the temperature as high, since it never exceeds 4200° Fahr.

Uses of Oxy-Hydrogen for Welding.—Since it is difficult with oxy-hydrogen blowpipes to melt the edges to be welded, even in thin pieces, it is practically impossible to make satisfactory welds of steel exceed-

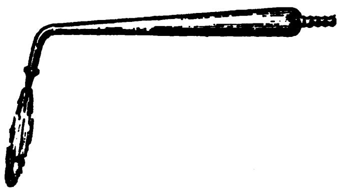

Figure 2.—Oxy-hydrogen Blowpipe Working with the Gases Pre-mixed

ing ¼ inch in thickness. Its use is therefore limited to work up to about $\frac{3}{16}$ inch in the case of iron or steel. Even within these limits the welds are not as good and cost more than oxy-acetylene welds. The cost of the installation differs but little from that of an oxy-acetylene plant. A considerable amount of practice is required to enable the workman to properly regulate the oxy-hydrogen blowpipe. Figure 2 shows the type of blowpipe used in this process.

OTHER GAS FLAMES

Oxy-Coal Gas.—This term is given to the flame produced by the combustion of a mixture of oxygen and

illuminating gas. In 1838 Debassyns de Richemont replaced the hydrogen in an oxy-hydrogen blowpipe with coal gas. Brazed joints and autogenous welds in lead were obtained with the flame thus produced. When the oxy-hydrogen and oxy-acetylene processes became known industrially, due to the production of oxygen at a low price, the use of coal gas for obtaining autogenous welds was again considered. The process was tempting because it made a cheap and easy installation possible in any workshop supplied with gas.

Welding by oxy-coal gas has not had and cannot have a very wide application as can be easily shown. Illuminating gas is a mixture of various gases and its composition is not absolutely constant. One cubic foot of average quality contains about:—

0.5 cubic foot of hydrogen.
0.35 cubic foot of methane.
0.08 cubic foot of carbon monoxide.
0.02 cubic foot of carbon dioxide.

The combustion of one cubic foot of this gas produces 600 to 750 B.T.U. The temperature of the oxy-coal gas flame is no higher than that of the oxy-hydrogen flame and the utilization of the heat is no better. Further it gives results that are decidedly bad from the viewpoint of the quality of the weld.

It has been shown that in oxy-hydrogen welding the strong oxidation of the metal can only be avoided by diluting the water vapor produced with a large excess of hydrogen. The oxy-coal gas flame produces as much water vapor as the oxy-hydrogen flame, and therefore one should follow the same procedure. But, apart from the disadvantages produced by an excess of coal-gas in the flame, it would not be possible to

introduce an appreciable excess on account of its low pressures. Unlike hydrogen in the oxy-hydrogen process, the oxygen has to draw it by suction, and the quantity is necessarily limited.

The welds obtained by oxy-coal gas blowpipes are therefore always very strongly oxidized and excessively fragile, so that their resistance is practically nil. In fact, oxy-coal gas welds should be prohibited in all cases where the work is likely to be subject to strains, and little recommended for joints which do not require to be strong or tight. In iron and steel work one can only apply it on thin material.

The style of blowpipe used in this system is shown

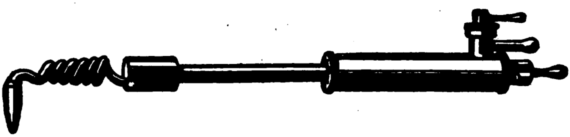

Figure 3.—Oxy-coal Gas Blowpipe

in Figure 3. It should also be noted that the arrangements for preheating the gases previous to combustion, with a view to obtaining a higher temperature in oxy-coal gas or oxy-hydrogen flames, do not achieve the desired result. This is because, if the temperature is increased, the water vapor dissociates with the absorption of heat, the two elements recombine much farther in the flame, thus giving back their heat of formation, but which has already been absorbed.

Oxy-Benz.—The term "oxy-benz" has been adopted to describe welding flames produced by the combustion of mixtures of oxygen and the vapors of benzine, benzol, gasoline, and all other liquid hydrocarbons. While these processes may prove to be of value in

special cases, they are not adapted to the ordinary applications of autogenous welding. One great defect in oxy-benz work is that it involves the use of a liquid fuel which must first be vaporized. This operation, even when semi-automatic, requires time and care on the part of the operator and regularity is very hard to obtain.

The blowpipe, a view of which is shown in Figure 4, is a very delicate and complicated instrument. The acetylene generator or the hydrogen cylinder used in the oxy-acetylene and oxy-hydrogen processes are replaced by a vessel containing the liquid, usually

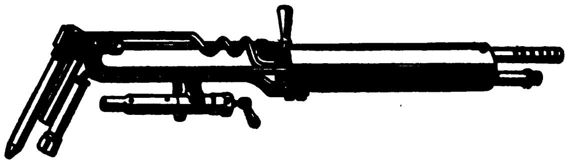

Figure 4.—Oxy-benz Blowpipe

under pressure. The use of a branch from the oxygen for obtaining this pressure is attended by danger and in order to avoid risk of explosion it is necessary to use devices which, while being very ingenious, are extremely complicated.

Conclusions on Welding Flames.—The great success of the oxy-acetylene welding process has given rise to various other methods and will no doubt lead to the development of others. There are for instance, liquid gas, Blau gas, vulcan gas, etc., but acetylene offers many advantages over all others so far offered, and it is the only process by which welds from the smallest to the very largest can be obtained while offering assurance of strength in the weld.

Oxy-hydrogen is inferior to the oxy-acetylene process, although giving better results than oxy-benz welding. Oxy-benz and similar processes have no value except for special applications and in cases where the work is not important enough to justify an oxy-acetylene installation.

CHAPTER III

OXYGEN

PROPERTIES OF OXYGEN

Oxygen is invariably the combustion agent used in autogenous welding with the blowpipe. It is necessary for those using it to be familiar with its properties, manufacture, storage, methods of use, etc.

Oxygen is, of all bodies, the most widely distributed in nature. It exists in a state of mixture in the air, which contains about one-fifth of its volume of this gas. Water is a compound of oxygen and hydrogen, containing nearly 89 per cent of the former element. Oxygen is found in nearly all mineral and organic substances.

This gas was isolated by Priestley in England, and Scheele in Sweden. Lavoisier studied its properties and gave it the name of oxygen.

Physical Properties.—Oxygen is a colorless, tasteless, and odorless gas. Its density is 1.1056.

One litre (about 61 cu. in.) of oxygen at 32° Fahr. and atmospheric pressure weighs 22.06 grains.

It is not very soluble in water; 100 volumes of water at 32° Fahr. can dissolve nearly 5 volumes of oxygen at atmospheric pressure.

Formerly, oxygen was considered a body not capable of existing in the liquid state. In 1877 M. Cailletet and Pictet succeeded in liquefying it by compressing it to 320 atmospheres and lowering its temperature to 220° Fahr. below zero. In the liquid state its density approaches that of water. Like all other gases, oxygen can be compressed.

Chemical Properties.—Among chemists oxygen is known by the symbol O. Its atomic weight is 16.

The characteristic property of oxygen is its power of supporting combustion. A glowing candle will instantly burst into flame if plunged into a jar of oxygen.

Iron heated to redness burns in oxygen.

The combustion is a chemical reaction between the oxygen and the body which burns in it. The product of the combustion is called oxide, and the metal is said to be oxidized.

Under the heading of combustion should also be placed slow combustion, in which oxidization takes place while the temperature of the metal is not especially high. Oxidization of metals by contact with oxygen or air is slow combustion. The intensity of this action increases with the heat, which accounts for the fact that most metals oxidize rapidly when red hot in air and of course much more rapidly when in contact with pure oxygen.

Manufacture of Oxygen.—Oxygen is usually prepared in the laboratory by heating manganese dioxide to bright red heat which causes it to give up one-third of its oxygen; or by heating potassium chlorate which likewise gives up its oxygen. If the potassium chlorate is mixed with about one-eighth its weight of manganese dioxide, the action is much more regular. These processes are not commercially useful. They were used when oxygen could not be secured in any other way. It is due to the manufacture of oxygen at a low price that autogenous welding has developed, and this development has stimulated inventors and manufacturers to search for processes or improve-

ments which would produce oxygen at still lower prices.

Electrolysis of Water.—Water is composed of hydrogen and oxygen and may be divided into these elements, the two gases being collected separately. This operation is easily carried out by means of electricity and is called electrolysis. Water, to which a small quantity of sulphuric acid or potash has been added, is treated with an electric current in an electrolizer. The oxygen comes from the negative pole and the hydrogen from the positive pole. The gases are then collected separately and conveyed to gasometers. The hydrogen is used for oxy-hydrogen welding, filling balloons, etc. Oxygen made by this process is generally very pure, but the electrolizers require great care and much supervision to avoid mixtures of the two gases, such mixtures being extremely dangerous. This risk has been greatly diminished in recent years by the use of automatic indicators which give an alarm in case of the diffusion of the oxygen and hydrogen.

The process is considered more costly than that of extracting the oxygen from the air, but according to the scale of production and the general conditions of working it may compete with it.

Extraction of Oxygen from the Air.—Attempts were made long ago to extract oxygen from the air, where it exists as a simple mixture with nitrogen (nitrogen 79 per cent, oxygen 21 per cent).

A mechanical treatment of air rich in oxygen was tried, but a complete separation of the two gases was not possible. This process was abandoned, but, without doubt, the last word has not been said, and there

is still the possibility of it being applied industrially some day.

Boussingault devised a method for the extraction of the oxygen from the air which is still being used, although going out of use. It consists in gently heating baryta (BaO) to dull redness in air. The oxygen combines with the baryta forming the dioxide (BaO_2), but at a bright red heat this parts with the additional oxygen with the reproduction of baryta. By thus alternately varying the temperature a regular production of gas can be obtained.

The process of Mothay and Maréchal consisted in passing air over a heated mixture of manganese dioxide and soda. The substance absorbs the oxygen and is converted into manganate. Water vapor is then passed over the manganate to decompose it, that is, to liberate the oxygen which it has absorbed, which regenerates the mixture of manganese dioxide and soda.

During the last few years the economical production of oxygen has been obtained by the liquefaction of air and the separation into its two constituents.

Professor Linde was the first to work out an industrial arrangement for the liquefaction of air, and for the separation of the liquid into two constituents, oxygen and nitrogen. Claude, Pictet, Lévy, and Helbronner, completed the problem, and designed extremely ingenious plants for the economical production of liquid air and its rational distillation.

We can only give the main outlines of the operations. The air to be liquefied is first compressed, then expanded. This lowers its temperature and ultimately reaches liquefaction.

Although the oxygen and the nitrogen liquefy simultaneously, Claude succeeded in obtaining the first jet

of liquid rich in oxygen, which, by a process of rectification, gets rid, little by little, of its nitrogen. The Linde process consists of the fractional distillation of liquid air, which brings about the production of pure oxygen. Other plants have been designed besides these, using more or less these two systems or their combination, hence the patents and claims of these are contested by the others.

As a general conclusion one might say that the liquid air process is the most economical. It is also the one that has been most developed. Obtaining economical autogenous welds is the result of the reduction of price in oxygen due to the successful production of oxygen from the air.

Other Processes.—Other processes for the production of oxygen for industrial use have been invented and used with varying degrees of success. The use of potassium perchlorate is an improvement over the older methods, especially as this body is made to give up the greater part of its oxygen by auto-combustion. It forms the basis of a product known as oxygenite.

Oxygenite is a yellow substance of sandy appearance. It is unaffected by air and does not deteriorate if stored in a dry place. A special apparatus, a sectional elevation of which is shown in Figure 5, is used for the combustion and the storing of the oxygen under pressure. It is only necessary to place the product in a chamber for the purpose, introduce it into the apparatus as shown at the top of Figure 5, light, then close the gas-tight cover. After a few minutes oxygen is produced under pressure. One pound of oxygenite supplies about four cubic feet of oxygen. The cost of oxygen produced in this way is much higher than the price of oxygen produced from

air or by electrolysis from water. The only advantage connected with the oxygenite process is that its use makes it possible to produce the oxygen at the place

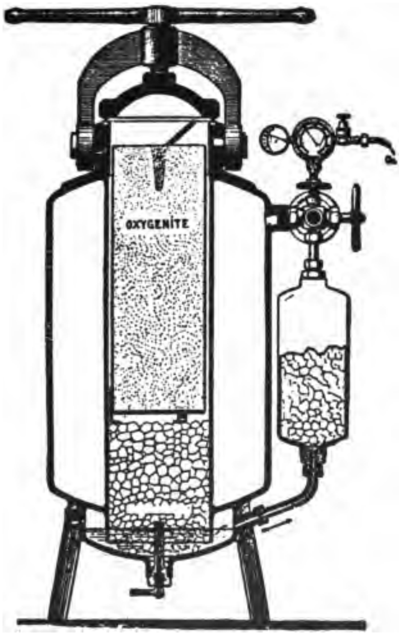

Figure 5.—Apparatus for the Production of Oxygen from Oxygenite

of consumption and in localities far from oxygen producing works.

The cost of renting and the transportation of the steel cylinders in which compressed oxygen is sold, makes their use impossible in places far removed from

industrial centers and in these places oxygenite may render valuable service.

Another method of obtaining oxygen is by the use of epurite, a mixture of chloride of lime, iron sulphate and copper sulphate. This mixture is soaked in water, when the generation of gas takes place slowly. This is a more costly process than the oxygenite method.

Oxygen from Chlorate of Potash.—An apparatus for generating oxygen from chlorate of potash consists of a furnace lined with fire brick, containing a gas or coal burner and an air-tight cast iron retort, cast iron buckets, scrubbers, gasometer, water cooled compressor, high pressure tanks and gauges.

To extract oxygen from chlorate of potash a small quantity of manganese dioxide is mixed with the chlorate and placed in a cast iron bucket; this is put into an air-tight retort of cast iron fitted in the furnace and heated until the oxygen is driven out. The pressure thus created forces the oxygen through the scrubbers which separate it from the chlorine gas and purify the oxygen. Pure oxygen is very necessary to obtain a perfect welding flame. From the scrubbers the gas enters the gasometer from which it is drawn by the compressor and forced into the pressure tanks; from these tanks it is let into the line as required by means of valves. By this process it is claimed that oxygen of 99 per cent purity is obtained. The apparatus also possesses the advantage of being easily installed in any locality.

OXYGEN IN CYLINDERS

Oxygen extracted from the air or secured by the electrolysis of water is delivered from the works in

steel cylinders under a pressure of about 1800 pounds to the square inch. These cylinders, tubes or bottles, as they are variously called, may be studied with advantage. They are constructed of steel. Figure 6

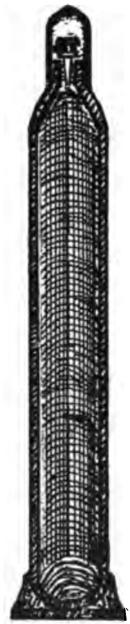

Figure 6.—Section of Oxygen Cylinder

shows a section of one of them. The walls are of sufficient thickness to withstand a much higher pressure than that to which the oxygen is compressed. The cylinders are tested by a hydraulic apparatus to twice the working pressure or about 5000 pounds per square inch. Oxygen can not be divided into other gases, its

use is therefore safe from danger of explosive burning. The base of the oxygen cylinder may be encased in a stand, enabling the cylinder to be placed upright and preventing sudden shocks during manipulation. The top of the cylinder is dome shaped and terminates in a threaded portion inside of which the cylinder valve is carried and over which may be screwed a protecting cap which entirely covers the valve stem and handle.

Compression of Gas into Cylinders.—The oxygen when obtained is stored in large tanks, or gasometers, from which it is taken to the compressors and pumped into the cylinders. Several cylinders are filled simultaneously from the compressors. When gas is compressed, heat is produced and when a gas expands cold is produced or heat absorbed. Compressing the oxygen causes heat and inasmuch as a heated gas occupies more space than a cold gas, the cylinder cannot be filled with as much oxygen as if this heating did not take place. This makes it necessary to compress the gas to a greater degree than the actual gauge pressure will show after cooling.

As a result of the oxygen having come in contact with water in the gasometer or bad working of the compressors, a certain quantity of water vapor is carried into the cylinders which will condense when the cylinder cools and collect as water in the bottom of the cylinder.

Volume of Oxygen in Cylinders.—Oxygen cylinders usually employed in welding contain volumes of gas ranging from 10 to 200 cubic feet when not under compression. The volume which a compressed gas would occupy at atmospheric pressure is found by multiplying the capacity of the cylinder by the pres-

sure of the gas expressed in atmospheres of 14.7 pounds each.

An interesting problem is as follows: Assume that a certain torch uses 28 cubic feet of oxygen per hour and that the welder is about to start on a job of welding that will require one hour to complete.

He has at his disposal but one 100 cubic feet cylinder of oxygen under a pressure of 50 atmospheres or 735 pounds. Owing to the fact that blowpipes usually consume more than their rated capacity, an allowance should be made for this, and in this case an increase of about 25 per cent over the rating will be allowed, making the actual volume of gas consumed 35 cubic feet per hour.

Suppose the internal capacity engraved on the cylinder is 0.83 cubic feet. Since the pressure is 50 atmospheres, the volume of oxygen at the disposal of the welder is equal to $.83 \times 50 = 41.5$ cubic feet.

With 41.5 cubic feet of gas in the cylinder and an estimated consumption of 35 cubic feet, also deducting the 2 or 3 cubic feet that will remain in the cylinder when the pressure is too low to force the gas to the blowpipe, the welder can safely undertake the work, although it would be advisable to work rapidly and endeavor to finish in less than one hour.

It is, of course, understood that such a calculation is only approximate, but in practice it can become of real value to the welder.

Boyle's Law, which is, that the volume of a gas diminishes in the same ratio as the pressure upon it is increased, is only approximate. For oxygen it requires serious corrections, especially at certain pressures. The law is only strictly true when applied to so-called perfect gases (which are imaginary), and oxygen is

not among these. The scientist Amagat drew up tables of corrections for the gases mostly used, and among others for oxygen.

When oxygen is compressed, say, to 120 atmospheres, the cylinder contains more than 120 times its volume of gas reckoned at atmospheric pressure.

The Amagat correction varies with the pressure, and therefore to calculate accurately the quantity of oxygen remaining in a partly spent cylinder it would be necessary to have a complete table of corrections for all pressures. In the case of compressed hydrogen the corrections to be applied are opposite to those of oxygen; that is, in order to have 120 times the volume of gas in the cylinder the hydrogen must be compressed to a higher value than 120 atmospheres.

We will now deal with the effect of temperature, because this is an important factor.

It has already been proved that the volume of a gas increases with an increase of temperature, and that this is true for a gas under pressure, the increased volume following Boyle's Law. Consequently, when the temperature of oxygen in a cylinder is increased or diminished, the pressure rises or falls.

The calculations are usually based on a temperature of 15° Cent. (59° Fahr.). This is the temperature for which Amagat constructed his curves of correction for Boyle's Law. For calculating the volume of the gas stored in oxygen cylinders the pressure must therefore be taken at 59° Fahr. (15° Cent.).

Pressures and Temperatures.—An investigation indicated that oxygen compressed into a cylinder at 15° Cent. and a pressure of 150 atmospheres is raised to the following pressures as its temperature is increased:—

At 20° Cent.........152.8 atmospheres.
At 25° Cent.........155.6 atmospheres.
At 30° Cent.........158.4 atmospheres.
At 35° Cent.........161.4 atmospheres.

And if the pressure is lowered:—

At 10° Cent........147.2 atmospheres.
At 5° Cent........144.4 atmospheres.
At 0° Cent........141.6 atmospheres.
At —5° Cent........138.8 atmospheres.

These figures show clearly that in calculating the volume of oxygen under pressure, temperature is an important factor and must be taken into account. The temperature to be taken is that of the surrounding air in which the cylinder has been resting for several consecutive hours.

Another point to be remembered is that, directly after a quantity of oxygen has been taken out, the temperature of that remaining in the cylinder is considerably lowered as a result of the expansion. For this reason the gauge pressure on the reducing valve of a cylinder always rises a little after a large delivery, and as the cylinder regains the normal temperature of the surrounding air, the pressure will again rise.

Therefore, in order to make an accurate calculation of volume under existing conditions of pressure and temperature it is necessary:—

(1) To apply the Amagat corrections.

(2) To express the pressure in atmospheres.

(3) To correct for temperature, which should be at 15° Cent. or 59° Fahr.

Handling of Oxygen Cylinders.—Cylinders containing compressed oxygen can be handled without any special precautions. For use they are placed according to their shape, either upright or horizontal.

A very good arrangement consists in placing them in an inclined position on a support 10 to 15 inches high, thus bringing the valve into a good position for handling.

Care should be taken to prevent them from falling which is liable to occur if the floor is not level. Such accidents do not affect the cylinder, but may injure the workman or damage the reducing valves.

Cylinder Valves.—Two valves are used on the oxygen cylinder. One is mounted directly in the cylinder and remains with it during shipment. It prevents loss of the gas until wanted for use. This is a needle valve ending in a squared portion or small hand wheel on top of the cylinder. The valve stem passes down through a stuffing nut and box into the oxygen space. The other valve is known as the reducing valve, its purpose being to take the gas from the cylinder at a pressure running up to 3000 pounds per square inch and deliver it to the torch at 5 to 20 pounds required for welding. This reducing valve is attached to the cylinder after receipt from the oxygen works, and is kept as part of the welding installation.

Practically the only thing the workman has to do with the cylinder valve is to open and close it as the gas is wanted. If, on the arrival of the cylinders, the valve is very hard to open, the welder should make sure of its working before placing the reducing valve in position, so that any powdered oxide or other dust is blown away. The oxygen on escaping into the air produces a violent hissing; the valve is opened and closed alternately two or three times, and then tested for being gas-tight when closed. The slightest escape can usually be detected by the ear.

All being well, it only remains to screw on the re-

ducing valve, and the only important precaution is to open the cylinder very slowly at each starting. The valve may be hard to manœuver or shift, either at the union for the reducing valve or at the stuffing-box nut under the key or handwheel.

In no case should oil, grease, soap, or any fatty matter be used. Oxygen under pressure has an oxidizing

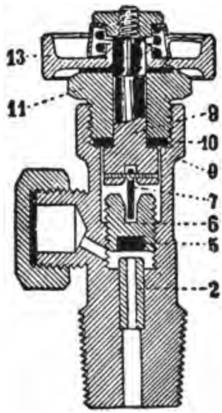

Figure 7.—Section of a Cylinder Valve

action on oil, grease and fatty bodies, and the heat produced can start combustion; the conflagration may spread to the ebonite part of the valve and destroy the steel parts. The oxygen then escapes in large quantities from the cylinder, thus tending to produce a brisk combustion by contact with a lighted body, and serious accidents may result.

If, after closing the valve, there is still an escape, which is shown by the pointer of the gauge rising after the valve of the cylinder has been closed, try to

screw the valve tight, but without overdoing it, because it becomes difficult to reopen.

If the leak still continues, remove the reducing valve and open the valve briskly two or three turns and then immediately close; repeat this two or three times. If this proves a failure, it only remains to use the reducing valve for obtaining tightness. the regulating screw

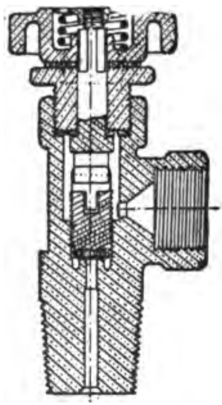

Figure 8.—Section of a Cylinder Valve

being completely free in such a manner that the pressure does not act on the diaphragm.

Figures 7 and 8 show sections of two types of valves.

Leaks sometimes occur past the nut of the stuffing-box under the key or handle (9 in Figure 7); this is because the packing (10 in Figure 7) is worn. This can be changed by screwing off the nut, but before carrying out this operation one must make sure that the valve is entirely closed, because, on unscrewing, the pressure can, with great violence, blow the various details out, and the cylinder be entirely emptied.

Great caution is recommended in dismounting a valve of a cylinder under pressure, and it is better to abstain entirely if one is not perfectly familiar with the operation. In this case, and when the leak is considerable, the cylinder should be returned to the makers with an explanatory label attached to it.

As previously mentioned, there is always a small quantity of water in the cylinder. Care should be taken to remove this and so avoid freezing in the valve, especially in winter, when using a blowpipe of large delivery, as the expansion produces considerable cooling. It is only necessary to invert the cylinder so as to collect the water near the head, and then expel the liquid in jerks by successively opening the valve. Following this, put back the cylinders on end and, before fixing the reducing valve, operate for the expulsion of dust in the manner previously indicated.

If at any time the valve should freeze and it becomes necessary to melt the ice, warm water should be used. Never use a flame as there is danger in such practice. However, if the water has been carefully expelled from the tank, there can be no freezing of valves under ordinary conditions.

In order to avoid excessive expansion of the gas and consequent increase in pressure the cylinders should always be kept away from a warm place, in sunshine, near fires, radiators, etc.

After emptying the cylinder the valve should be closed, the cap put on and the cylinder returned to the manufacturers.

PURITY OF OXYGEN

Oxygen obtained from liquid air may contain more or less nitrogen. That obtained by the electrol-

ysis of water might contain a little hydrogen. These two gases are considered as impurities. If hydrogen were present to an appreciable extent, it would produce the disadvantage of forming with the oxygen an explosive mixture. It has been demonstrated that in the cutting of iron and steel by blowpipe cutters the presence of nitrogen, even in small quantities, has an adverse effect on the quality and rapidity of the work.

Commercial Guarantee.—Oxygen compressed in cylinders is generally delivered containing 96 to 99 per cent of oxygen, but the commercial guarantee may be as low as 95 per cent; that is to say, if analysis gives a result lower than this figure, no claim can be made except in case of special agreements. Oxygen for use in cutting should be as pure as possible and have a minimum guarantee of 97 per cent.

Analysis.—The purity of the gas is easily ascertained by acting on a definite quantity of oxygen with a chemical which rapidly absorbs the gas but leaves the impurities, hydrogen, nitrogen, carbon dioxide, etc., intact. The quantity of gas absorbed, compared with the original volume, shows the degree of purity.

The analysis is made in graduated test tubes. The absorbent liquid takes the place of the oxygen absorbed so that when the absorbtion is complete, it is only necessary to read off the level of the liquid to find the percentage of pure oxygen. Until recently the absorbing liquid generally used was a mixture of saturated solution of pyrogallic acid and potash or caustic soda. The preparation and use of this liquid presented many difficulties to those not accustomed to gas analysis. In addition to this the alkaline pyrogallate solution has the disadvantage of absorbing

carbon dioxide and of liberating bubbles of carbonic oxide which vitiates the result. It was formerly the practice after analysis to add 2 per cent to the observed result, because it was always about this value below the true percentage.

Analysis by Sodium Hydrosulphite.—A more practical process than the above has been devised, which consists in using a solution of hydrosulphite of sodium as the absorbing agent. By means of this process purchasers of oxygen can easily test the purity of the gas they are using.

Sodium hydrosulphite is a white salt which is not acted on by the oxygen in the air when in a dry state. It must be preserved in well stoppered bottles in a dry place.

A solution in water has a great affinity for oxygen. The solution becomes a yellowish brown color when absorbing oxygen. The anaylsis is performed with the aid of a tube having a valve at each end, called a burette. The straight part of this tube is graduated to 100 cubic centimeters.

The tube is connected to the oxygen cylinder by a branch tube, the cocks are opened and the oxygen is allowed to run through the burette for 20 to 30 seconds to expel all air. The valves are then closed successively from the oxygen cylinder toward the outlet of the burette so that the sample will not be confined under pressure.

The burette is then transferred to a vessel containing hydrosulphite dissolved in water and one end of the burette is dipped into this solution. The strength of this solution should be about 15 per cent.

The valve on the burette which is next the solution is now opened so that the oxygen and the solution come

together and the oxygen is absorbed. The absorption can be hurried by carefully closing the valve in the burette and shaking it, causing the liquid to present a larger surface to the gas. The burette is again placed in communication with the solution and the cock opened, and the liquid rises in the tube. By repeating this operation two or three times the analysis is ex-

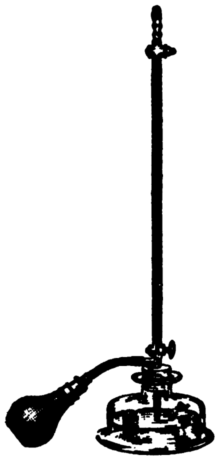

Figure 9.—Analysis of Oxygen

tremely rapid. When the liquid ceases to rise any more the reaction is terminated, and by reading the level of the liquid the purity of the oxygen is known, which may reach over 99 per cent, that is, the absorbing liquid almost completely fills the tube.

A few precautions are necessary, especially in filling the tubes, to make sure that all air is expelled, and to manipulate in such a manner as to avoid introduc-

tion of air through the cocks, under the effect of a vacuum, in the inserted end.

One can facilitate the rising of the liquid at the beginning by creating a slight pressure in the vessel containing the absorbing liquid. This can be done either by pushing down the cork through which the end of the burette passes, or by air from an india rubber bellows (Figure 9).

It is possible to operate differently; for example, the hydrosulphite solution could be introduced into the burette by means of a funnel fixed above the upper cock; on opening the cock the liquid rapidly flows down, taking the place of the oxygen which it absorbs.

CHAPTER IV

ACETYLENE

Acetylene was discovered in 1836 by Humphrey Davy, an English chemist, and Berzelius, a Swiss chemist. They found that the residue which had been obtained incidentally in the production of metallic potassium was capable of decomposing water with the evolution of a gas which contained acetylene. It is also produced during the incomplete combustion of certain gases. Thus, when a Bunsen burner lights at the bottom of the tube, acetylene is produced. But until the industrial manufacture of calcium carbide it remained a laboratory gas.

Chemically, acetylene consists of carbon and hydrogen, and is represented by the formula C_2H_2, meaning that it has the constant composition of 24 parts by weight of carbon and 2 of hydrogen, or 92.3 per cent of carbon and 7.7 per cent of hydrogen. Of all the hydrocarbons it is the richest in carbon. Acetylene is a colorless gas, which, when pure, has an odor which is not unpleasant. The penetrating and disagreeable odor is due to impurities, notably phosphoretted hydrogen, hydrogen sulphide, and the polymers of the gas; these latter result from the heat generated in certain generators.

Acetylene is lighter than air in the proportion 91 to 100; its specific gravity or density is therefore said to be 0.91. One cubic foot of the gas weighs 0.074 lb. One lb. of the gas occupies, under standard temperature and pressure, 13.65 cubic feet.

Acetylene is soluble in a large number of liquids.

Under ordinary temperature and pressure, water dissolves little more than its own volume, essence of turpentine and petrol 2 volumes, benzene 4, pure alcohol 6, and acetone 25. The solubility increases with the pressure. Acetylene is scarcely soluble in water saturated with marine salt.

When heated to a temperature of about 600° Cent. (1112° Fahr.) acetylene polymerizes into a number of products more or less related to benzene. The formation of benzene by polymerization takes place with disengagement of heat (178 calories or 44 B.T.U.).

Acetylene under atmospheric pressure becomes a liquid at —82° Cent. (—115° Fahr.) and a solid at —85° Cent. (—121° Fahr.).

Acetylene under no pressure or under a slight pressure is not explosive, but this is not the case when compressed.

Berthelot showed that acetylene, subjected to a pressure of 1½ atmospheres, can decompose into its elements under the influence of a shock, slight heating, or any percussion whatever. Such decomposition produces a violent explosion.

In practice the maximum should be much lower than this, and acetylene should never be kept under a pressure of more than a few pounds. On the other hand, acetylene absorbed under pressure by liquids which dissolve it, such as acetone, is absolutely safe.

Acetylene is an endothermic body, that is, it is formed with the absorption of heat. This heat is then given up at the time of combustion contributing powerfully to the rise in temperature in the flame. Mixtures of acetylene and air, and, of course, of acetylene and oxygen, explode violently when ignited. The temperature of ignition being very low, a spark is suffi-

cient to set fire to the mixture. The formation of such mixtures should be avoided, and most certainly their ignition. The propagation of the flame can take place through extremely small holes. The explosion of a vessel of one quart capacity containing a mixture of acetylene and oxygen is violent enough to cause the death of a person near it. It is very easy to avoid the formation of such mixtures as will be seen later.

Carbide of Calcium.—The discovery of the process of the manufacture of carbide of calcium is due to the work of a French chemist, Moissan, and an American electro-metallurgist, Wilson.

Carbide of calcium consists of calcium and carbon and is represented by the formula CaC_2. It consists of 62.5 per cent of calcium and 37.5 per cent of carbon. The color varies from earthy gray to luminous black, sometimes possessing a range of colors similar to tempered steel. The texture is usually massive and crystalline, although in some cases spongy. Neither the color nor the texture serves to indicate the good or bad qualities of the carbide.

Carbide of calcium has the hardness of stone. Its specific gravity ranges from 2.2 to 2.3. It is noninflammable and it softens and melts at about 5400° Fahr. In the presence of water vapor or water it decomposes into acetylene gas and oxide of calcium (lime):

$$CaC_2 + H_2O = CaO + C_2H_2$$
$$64 + 18 \quad = \quad 56 + 26$$

According to this equation, 64 parts by weight of carbide requires 18 parts by weight of water, or 1 pound of carbide requires 0.225 pints of water. These are purely theoretical quatities and do not take into account the evaporation of the water and the absorption of the water by the lime which forms quick lime.

In practice it is necessary to use 1.2 to 1.6 pints of water for each pound of carbide in those generators known as water to carbide and dripping; and 5 to 5.5 pints of water to each pound of carbide in carbide to water types of generator. These quantities insure that the lime residue may be removed in liquid form.

Theoretically, one pound of carbide yields 5.5 cubic feet of acetylene at standard temperatures and pressure. The action is always accompanied by a rapid liberation of heat; 226 calories or 900 B.T.U. for each pound of carbide.

Manufacture of Carbide.—Carbide of calcium is made by fusing a mixture of lime and carbon (coke or anthracite), in the proportion of 56 parts by weight of lime to 36 parts by weight of carbon, in an electric furnace, the temperature of which is about 7200° Fahr. The carbon should not contain more than 5 per cent of ash and the lime should be as free as possible from phosphates. The economical production of carbide depends to a great extent on the low price of electrical energy. Manufacturers of carbide cannot establish themselves unless a minimum power of from 2000 to 3000 horse power can be utilized.

Under the enormous temperature of the electric furnace, the lime and carbon combine and the liquid carbide which results flows easily, then cools and solidifies in large blocks. As soon as they are sufficiently cool, the blocks of carbide are conveyed to the crushing and granulating room where the carbide passes through crushers. The pieces are then sorted with sieves and graded according to size. Part of the crushed carbide is carried to the granulating apparatus which separates it into pieces of regular small size. The dust is removed and the graded carbide

is packed in drums, the covers of which are tightly sealed.

Classification.—The sizes packed in drums are designated as follows:

(1) Lump, a large size (3½ in. × 2 in.), containing nothing smaller than two inch pieces.

(2) Egg, a medium size (2 in. × ½ in.), containing nothing smaller than one-half inch pieces.

(3) Nut, an intermediate size (1¼ in. × ⅜ in.), for use in carbide to water machines using larger than quarter and smaller than egg. Machines especially made to use quarter size cannot use nut size.

(4) Quarter, a finely crushed size (¼ in. × $\frac{1}{12}$ in.), all small pieces and adapted for use in generators in which finely crushed carbide is fed into water.

Analysis of Carbide.—The exact gas yield of carbide of calcium cannot be measured by the volume calculated from the meter reading, nor by the delivery at the blowpipe, nor by the length of time taken to exhaust a certain quantity of carbide. These indications are of some use for comparison of different samples of carbide, provided the gas is always liberated under identical conditions. They give an approximate idea of the respective qualities, but are always liable to errors.

The accurate analysis always necessitates the employment of a special apparatus, which will indicate accurately the amount of gas liberated by a sample. Figure 10 shows the apparatus used for the accurate analysis of carbide.

ACETYLENE GENERATORS

General Principles of Production.—The production of acetylene by the action of water on carbide of

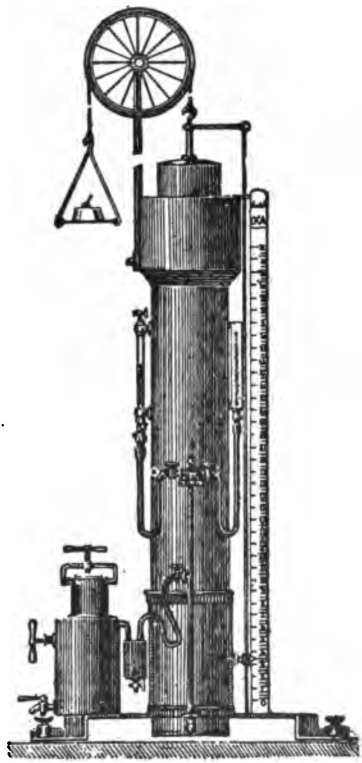

Figure 10.—Apparatus for Analysis of Carbide

calcium is chemically one of the simplest reactions, but in practice it is not so simple. The two prin-

cipal difficulties connected with the process are heating and over production.

Heating.—This is due to two causes. In the first place, since water consists of hydrogen and oxygen, the dissociation of these two gases takes place with the absorption of heat. On the other hand, the oxygen that is liberated combines with the calcium carbide and produces by the reaction more heat than is absorbed by the first reaction. The heat liberated exceeds 226 calories, or 900 B.T.U. per pound of carbide; that is, one pound of carbide would raise the temperature of one gallon of water through 90° Fahr. No device nor arrangement can reduce the quantity of heat liberated, but the temperature of the mass may be controlled. For instance, if an excess of cold water is used, the boiling temperature of the water cannot be reached, but, if the carbide is in excess in proportion to the water, the temperature can reach higher values. This causes the water to vaporize and react with the mass of carbide, thus supplementing the heat and under the influence of heat the lime can give up its water, which it retains strongly at low temperatures, to the carbide. These reactions continue, and if there is no external cooling, the temperature continues to rise. Lime being a bad conductor of heat, the mixture can become red hot.

The disadvantages resulting from the generation of acetylene at a high temperature are of two kinds—polymerization and great impurity.

Polymerization.—Under the influence of heat, acetylene polymerizes or condenses into liquid or solid products. This action takes place more readily during the formation of the acetylene than after generation. Numerous experiments have shown that these poly-

mers are formed in acetylene generators at a temperature of 266° Fahr. These tarry substances become fastened on the lime and discolor it yellow. Being formed from the acetylene they correspond to a loss of gas.

Impurity.—This is a serious disadvantage. Carbide, when acted upon by heat, gives up sulphides. Water decomposes these into hydrogen sulphide and organic sulphur compounds which are detrimental to acetylene. The higher the temperature of production the more impure the gas. Heating imparts to the gas the unpleasant odors of the sulphur polymers.

Excess Production or "After Generation."—No acetylene apparatus produces the gas in the proportion to which it is consumed. The production therefore has necessarily to be either in excess or in deficiency. The production should be in advance, and a sudden stoppage of consumption cannot possibly correspond to the abrupt arrest of the reaction.

The reaction continues, and this phenomena has received the name of excess production or "after generation." In dipping and water to carbide apparatus, it is necessary to take in to account the fact that the slaked lime which covers the carbide at the moment when the water ceases to be in contact, gives slowly to the carbide the water it requires, which brings about the liberation of acetylene, right up to dryness.

It is evident that for any particular generator, heating and after generation are in direct relation to the delivery. It is therefore impossible to formulate rules on these points without taking into account the delivery.

With reference to the maximum delivery of any particular apparatus:—

(1) The heating should never exceed a temperature of 130° Cent. (266° Fahr.).

(2) It should be possible to accumulate and use the after generation in case of stoppage.

Classification.—Acetylene apparatus can be divided into two classes:—

(1) Apparatus for intermittent production, called also non-automatic, in which the quantity of gas is prepared beforehand, and kept in a gasometer of a size suitable for the maximum consumption for one or several days. Such apparatus is constructed on the principal of the fall or immersion of a fixed quantity of carbide into a mass of water.

(2) Automatic apparatus, in which acetylene is produced in proportion to the consumption, such apparatus being mostly employed. Automatic apparatus can be divided into three main classes, viz., water to carbide, dipping or contact, and carbide to water.

The water to carbide apparatus is on the principle of a gasometer with a movable bell, or on the principle of the flowing back of water from the gasometer. The automatic function is brought about in the first case by the movement of the movable bell, and in the second case by the change in pressure.

In the dipping or contact generators, the carbide can be fixed and the water moving, or the water fixed and the carbide moving.

In the carbide to water generators carbide of all sizes, broken or granulated, is used. The carbide is usually automatically regulated by the movement of the movable bell.

Comparison of Systems.—Every system for the production of acetylene has its advantages and disadvantages. Before attempting to describe these it

should be noted that these advantages and disadvantages come more or less into consideration according to the construction of the apparatus and the use to which it is to be put. In other words, any particular advantage or disadantage may be increased or decreased according to the particular use for which a given acetylene plant is designed.

Water to Carbide.—Figure 11 is a sectional elevation of one apparatus, showing the principles. Com-

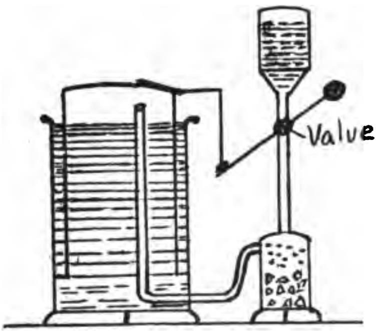

Figure 11.—Section of Automatic Water to Carbide Generator

pared to carbide to water generators, it has the disadvantage of necessitating longer and less convenient cleaning, producing less pure gas and of losing gas, especially in the case of sudden stoppage with a gasometer of too small size.

Figure 12 shows a complete generator of this type. An advantage in favor of this system is that the generator consumes less water, is simple in its working, absolutely safe and produces an excellent quantity of gas, especially if the after generation is well stored.

Dipping.—These generators, illustrated in Figures 13 and 14, cause the greatest amount of heat and

Figure 12.—One Type of Automatic Water to Carbide Generator

after generation and produce the most impure gas. However, their great simplicity renders their use advantageous for small portable plants having small de-

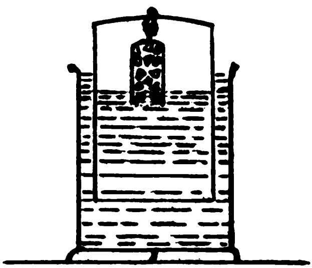

Figure 13.—Section of Automatic Dipping Generator

livery and which have to continue generation until the whole of the carbide is used up. This method should be rejected for large generators.

Carbide to Water.—Figures 15 to 19 illustrate the various types of generators used in this process. Its

Figure 14.—One Type of Automatic Dipping Generator

advantages and disadvantages may be enumerated as follows: The gas is cool, free from ammonia and hydrogen sulphide, and greater variation in delivery may

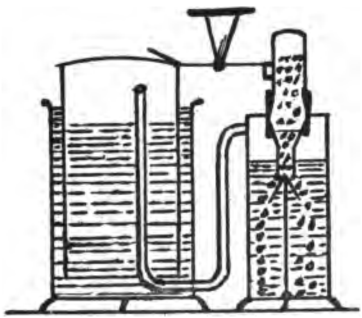

Figure 15.—Section of Automatic Carbide to Water Generator

be obtained. These generators may be easily cleaned and automatically emptied. Its disadvantages include the greater size for an equal yield of gas, greater

consumption of water and a great amount of liquid residue.

Granulated Carbide to Water.—The disadvantages

Figure 16.—Automatic Carbide to Water Generator

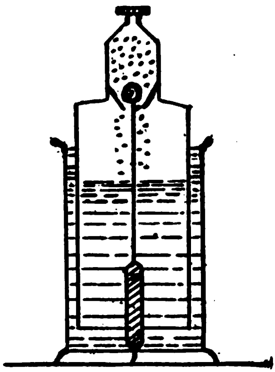

Figure 17.—Section of Granulated Carbide to Water Generator

of this type, as compared with the last one considered, include a smaller yield of gas and greater cost of carbide. All generators of this type in which the carbide is distributed by a conical valve or a flat valve (see Fig-

ure 17) are dangerous if the carbide capacity exceeds 2 to 5 pounds or where not working in the open air. It is possible, as a result of faulty working, for a piece

Figure 18.—Granulated Carbide to Water Generator

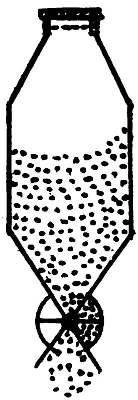

Figure 19.—Distribution of Granulated Carbide by Bucket Wheel

of carbide that is too large, or a foreign body to cause the entire charge to fall into the water at once. On the other hand, such an occurrence cannot take

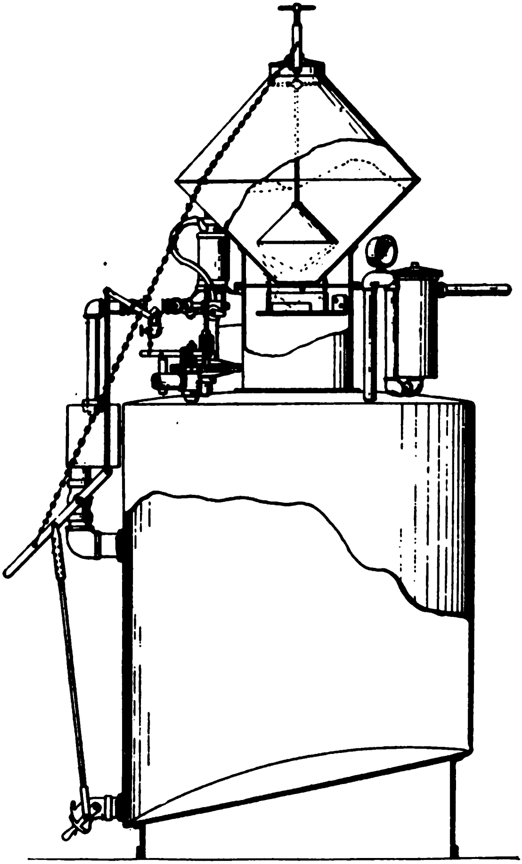

Figure 20.—Automatic Acetylene Generator

place if the granulated carbide is distributed by a bucket wheel (Figure 19) in which the distribution is definitely divided. The advantages of these generators

are in ease of charging and great variation in delivery rate. They are also less bulky and require smaller gasometers. The fall of the carbide may be quite frequent owing to the rapid decomposition of the pieces.

Automatic.—Figure 20 is a semi-sectional view of a generator, showing the working parts in detail, in which lump carbide is used. The carbide feed is by water motor which automatically maintains an even pressure of gas. It is equipped with a flash back pre-

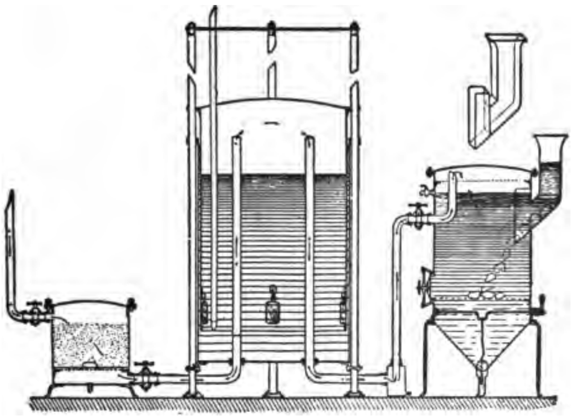

Figure 21.—Non-automatic Acetylene Generator

venter and a safety blow-off valve. Each time the generator is charged this blow-off valve is opened, which insures its always being in working order.

Non-Automatic.—Figure 21 is a sectional elevation of this type. It will be noticed that the general principles outlined in Figures 11 and 15 control the construction of this generator also. Non-automatic generators are used where gas is made in large quantities

in advance, being stored in gasometers for future use. While this system is very practical, it requires large space and is not well adapted for portable use.

Working Guarantees.—Certain guarantees for good working are necessary for all types of acetylene gen-

Figure 22.—Generator for Using the Carbide in Compressed Cakes

erators. For instance, each generator is rated for a given capacity, its normal charge of carbide being a certain number of pounds and its maximum output being a given number of cubic feet of gas per hour. The requirements then should be as follows:—

(1) For the rate of production the temperature of the carbide during decomposition should not reach the point at which acetylene undergoes polymeri-

zation, that is, there should be no tarry matters, benzene, nor any deposition of yellow material on the lime residue, when carbide of standard quality is used.

(2) The capacity of the gasometer should be sufficient to contain the acetylene given off after the water supply has been cut off, and there must be no excess of gas which will be blown to waste in the course of working.

(3) The pipes and cocks between the separate parts of the plant should be of such size that there can be no considerable variation in pressure, except in cases where variation of pressure is a function of the generating apparatus, even in case of maximum delivery.

(4) The pressure of the gas measured at the exit of the generator should be at least equal to 5 inches of water (if possible obtain 6).

(5) This pressure should be practically constant, the variation not exceeding half an inch in either direction, at any time during the working of the generator.

(6) The generator should be charged or emptied without any appreciable loss of gas. The quantity of air introduced in emptying and charging the generator should be so small that on mixing with the smallest quantity of acetylene which the gasometer can contain, it shall have no bad effect on the working of the blowpipe.

(7) Subject to ordinary wear and tear and provided the generator is used according to the manufacturer's rules and instructions, its good working should be guaranteed for a period of years.

Special Generators.—There have been made for welding purposes special acetylene generators which

give certain results which are of more or less importance. The special characteristic is the obtaining of an increase of pressure, which makes it possible to use blowpipes for medium pressure acetylene. Among other advantages obtained with these transportable generators is the absence of excess production, regularity of working and facility of employment, which makes them recommendable in practice. One type of this generator made for fixed installations is on the "flowing back of water from the gasometer" principle, and is capable of supplying acetylene at from 60 to 100 inches of water pressure.

CHAPTER V

PURIFICATION OF ACETYLENE

Impurities in Carbide and Acetylene.—Industrial carbide of calcium is not, and cannot be, a pure product. The chief constituents are, as we know, lime and carbon (metallurgical coke or anthracite), and no matter what care is taken will contain impurities. Compounds of sulphur are to be found in the best coke or coal, and phosphates in the purest lime. These impurities combine with calcium in the electric furnace, and, like carbide, the products formed are decomposed by water or heat, so that acetylene always contains, more or less, phosphoretted hydrogen and hydrogen sulphide, the amount depending on the generator used.

In addition to these two gases there should be included a little ammonia produced by the decomposition, by means of the water in contact with the lime, of the nitrodes and cyanamide which the carbide contains, due to combination with the nitrogen of the air at the moment of cooling.

To these chemical impurities it is necessary to add the solid matters in a fine state of division which are suspended in the gas and which have been given off by the lime at the moment of decomposition.

The phosphoretted hydrogen is always carried along with the acetylene; the hydrogen sulphide, ammonia, and the fine dust from the lime can be retained by the generator according to the system, but they generally go, more or less, with the acetylene.

Necessity for Purification in Welding with Oxy-Acetylene.—The impurities in the acetylene, even in

very small quantities, can do considerable harm to the strength of the welds.

Metallurgists endeavor to remove phosphorus and sulphur from their iron and steel, because these bodies alter considerably the mechanical qualities of the metal.

Now, strange coincidence, we find them exactly in that state as impurities in acetylene destined to melt the metal for obtaining welds, that is to say, ready to incorporate themselves in the welding zone, which should be particularly clean in order that the weld should be perfect.

Phosphoretted hydrogen and hydrogen sulphide by combustion produce phosphoric acid and sulphuric acid, and these are able to give up their phosphorus and sulphur to the metal being melted. It is true that the incorporation is not complete, but minute as it is, the weld is damaged—that is incontestable.

As far as other metals than iron and its alloys are concerned, this disadvantage does not exist, and in the case of copper, for example, the presence of phosphorus cannot be anything but favorable—but this is an exception.

The bad effects of the presence of phosphoretted hydrogen and hydrogen sulphide have been frequently proved, especially in the case where dissolved acetylene and acetylene from a generator have been employed successively. For example, in the manufacture of vessels destined to receive liquids or gases under pressure, cracks have been frequent when using non-purified gas from a generator, and infrequent in the case of dissolved acetylene, which is practically pure acetylene. It is in such cases that the superiority of purified gas has been realized.

It remains for us to examine the bad effects of the fine dust that is carried along with the gas, and which is so finely divided that it does not settle down with long standing in the gasometer nor by energetic washing. It is unnecessary to show the disastrous influence of these particles of lime when incorporated in the weld, and how the weld has been weakened; their elimination is absolutely necessary. A further disadvantage is that they obstruct the passage of the gas through the blowpipe and form a crust in the nozzle.

It is obvious, therefore, that the employment of gas which has not been purified presents many faults; the statement of which has not been exaggerated, and these disadvantages always exist in gas which has not been purified.

The oxy-acetylene flame in the case of impure gas is colored, and more difficult to regulate. Lastly, the anhydrides of phosphorus and sulphur produced by the combustion of impure acetylene spread in the atmosphere and have a dangerous physiological effect on the welders.

Process of Purification.—Washing of the gas only constitutes a slight purification and does not dissolve the phosphoretted hydrogen at all, and only partially the other impurities. Filtration through wadding, sand, or felt, etc., does not abstract the fine dust, and the passage of the acetylene through solid wood charcoal, coke, sawdust, etc., only constitutes, in general, an imperfect filtration.

The only practical way is to fix the impurities by chemical combination.

The question of purification has for a long time occupied numerous chemists, the manufacturers of

carbide and acetylene generators. It is extremely complicated, and presents difficulties of many kinds which it is not necessary to dwell on here.

Liquid purifiers have had to be abandoned completely, and solids have been made possessing the necessary chemical properties to fix the impurities and allow the acetylene to pass through without being attacked.

Purifying Materials.—Products containing alkali hypochlorites and alkaline earths which are able to retain by chemical combination phosphoretted hydrogen have been abandoned because they do not constitute a perfect purifier and produce other serious difficulties. The gas is not filtered and carries along free chlorine and lime dust, which are bad for welding, and which increase as the passage of the gas through the purifier is increased, following the use of a larger blowpipe. Hératol is one purifier much used. It is a powdered product of which the base is chromic acid.

Second, the purification with Hératol is too costly, and in addition to this, the use of Hératol for autogenous welding necessitates purifiers with a large surface. The passage of the gas through the purifier must not exceed 0.23 cubic feet of gas per hour per square inch of purifying surface. If this rate is exceeded, bad purification and heating of the mass takes place, bringing about decomposition of the acetylene. Thus for a delivery of 70 cubic feet per hour the Hératol purifier must have a minimum diameter of 20 inches. Although these conditions are not encouraging, the use of such a purifier is recommended, and those who have used it seem to be well pleased with the results.

Catalysol.—This is a purifying material which seems

to meet most of the requirements of autogenous welding. It is similar to Hératol in being a yellow powder with a specific gravity of 0.6 to 0.7. It consists of iron oxy-chlorides which act catalytically in such a way that the impurities of acetylene are completely oxidized by contact and the acetylene leaves the purifier in a pure and unattacked state.

The purifying power of catalysol is slightly superior to Hératol, but its principal advantage is its power of regeneration by simple exposure to the air, this being repeated three or four times until the product becomes inactive owing to the absorption of the impurities which it has extracted from the acetylene during its continued use.

Counting the first purifying with catalysol and three regenerations making four purifications in all, and, as each 2½ pounds of catalysol will handle 100 pounds of carbide; then one pound of catalysol will purify 160 pounds of average carbide, or about 770 cubic feet of gas, as compared to 160 to 200 cubic feet in the case of Hératol.

The process of regeneration of catalysol is very simple, it being only necessary to take the used material and replace it in its original box and after a few days it is again ready for use. The regeneration may be made more rapid by exposing it to the air in thin layers, care being taken that it does not become moist.

A special quality is prepared for autogenous welding installations which goes under the name of welding catalysol or catalysol S.

The velocity of the gas through the purifier can attain 0.7 cubic foot per hour for each square inch of surface. Taking an average of 0.5 cubic foot, the

capacity of the purifier can be diminished to half that required in the case of Hératol, and whatever be the velocity of passage of the acetylene, heating and decomposition of the gas need not be feared.

It may be added that the purifying material also performs the function of a filter in retaining the solid particles of dust carried along with the gas. It is also practically equal to the hydraulic safety valve as a guarantee of safety, since a strong layer of powdered material is interposed between the generating apparatus and the piping, which effectually opposes the return of the flame.

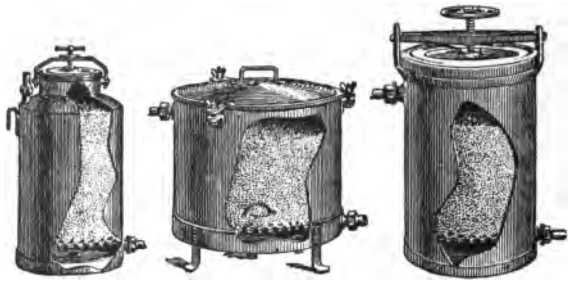

Figure 23.—Types of Purifiers for Catalysol

Such a product should appeal with certain success in the economical complete purification of acetylene for use in autogenous welding.

Purifiers.—The purifiers generally consist of cylindrical vessels (Figure 23) made of sheet-iron or steel closed by a cover, the joint being made of rubber. A perforated plate with very fine holes is supported in the vessel at a distance of 2 to 3 inches from the bottom, according to the type. The gas arrives under

the plate, and passes out near the top immediately under the cover.

The only conditions to observe when catalysol is used are as follows:—In order to avoid loss of pressure with the charge too high, the layer of material should not exceed 12 inches depth; 10 inches is more favorable. The purifying surface (surface of perforated plate) is calculated on the basis of 0.5 cubic foot per hour for every square inch of surface, and for the maximum consumption of the welding shop. With this data, and knowing the density of catalysol, which is from 35 to 45 lbs. per cubic foot, it is easy to calculate the charge of purifying material required for a given installation.

Table II.

DIMENSIONS AND CAPACITIES OF CATALYSOL PURIFIERS FOR WELDING.

Diameter of Purifier.	Height of Purifying Material.	Approximate Total Height of Purifier.	Maximum Delivery of Acetylene per hour.		Weight of Catalysol required.
inches.	inches.	inches.	litres.	cubic feet	lbs.
8	10	12½	600	21.2	11
11	10	13	1200	42.4	22
14	10	13½	1800	63.6	33
16	10	14	2400	84.8	44
18	11	15½	3000	106	66
20	12	16½	3800	135	88
22	12	16½	4700	166	110
24	12	16½	5600	198	132

The cross section of the passages through the cocks and points of the purifier should at least equal in area that of the piping. If the acetylene is not too highly charged with water vapor it makes no difference which direction the gas passes through the purifier.

The placing of a disc of felt or other porous material between the perforated plate and the purifying material enables the gas to pass through better and prevents material from falling through the holes into the double bottom. The purifying material should be simply poured in without packing down except lightly near the edges to prevent the formation of passages through the powder. The interior of the purifier and

Figure 24.—Position of Purifier with Regard to Acetylene Generators

the perforated plate should be carefully painted with an adherent coating, such as coal tar applied warm in order to prevent oxidation of the metal which rapidly attacks the plates even when galvanized or leaded.

Purifier Position and Maintenance.—The purifier may be placed in any position in the piping between the generator and the place of welding. The best place is near the generator, if there is room.

Maintenance simply consists in the replacement of the purifying material when it is destroyed. The exhaustion of the purifying powers of the material is indicated by a change in color in the material and in the welding flame. The flame will become yellowish and opaque in place of the usual transparent blue.

The simplest method of testing the purification of the gas is to take a 10 per cent solution of nitrate of silver (obtainable from any druggist) and place a drop of the solution on a filter paper or white blotting paper. Place the paper against the escaping acetylene and if the paper turns black in a few seconds it indicates that the purifying material is useless. If the paper remains white the purifier is still good. If it blackens slowly and slightly the purifier is slightly exhausted.

INSTALLATION AND MAINTENANCE OF THE ACETYLENE PLANT

Location of Plant.—The best location for an acetylene plant is in the open air under a roof or shed, but this is not always possible. A shed is satisfactory, provided it is well ventilated and all precautions are taken against carelessness. If it is impossible to find such a place then the plant should be located in the best ventilated part of the building and near daylight.

Should it be necessary to locate an acetylene plant in the interior of a building, it should be isolated by a partition, preventing all sparks and flame from reaching the plant. There should also be good circulation of air from outdoors to insure good ventilation. In no case should an acetylene generator, even a small one, be located in cellars, poorly ventilated places or dwelling places. It should be remembered that acet-

ylene, while not dangerous in itself, can form with air if escaping, a dangerously explosive mixture.

Regulations—Fire Insurance.—The manufacture and use of acetylene is regulated by laws and by the rules of the National Board of Fire Underwriters. There are definite rules governing installation and use of the apparatus, the storage of carbide, the construction of generators and the source of supply of oxygen gas.

It must be possible for the workman to reach any part of the apparatus easily, the generator must be protected against freezing, the escape pipe must pass outside the building and charging must not be done under artificial light other than incandescent electric bulbs encased in safety globes.

Carbide up to 600 pounds may be kept in insured buildings if in a dry, well ventilated place and in drums of not over 100 pounds capacity each. Only one of these drums may be opened at one time. The construction of all standard generators that comply with the rules will be certified to by a plate attached to the apparatus, stating this fact.

Charging and Cleaning.—It is necessary to be perfectly acquainted with the working and construction of the apparatus and to obtain from the manufacturer full and complete instructions relative to the manipulation of the plant.

The work of charging and cleaning should be done in the day time if possible. The generator, buckets, baskets, etc., should be cleaned with a strong flow of water and not recharged until they are perfectly dry. The baskets would be better for a second flow of water and should never be recharged until perfectly dry. In order to prevent the admission of air, or at least

to prevent any great amount entering the generator not provided with an air cock, it is necessary in carbide to water, automatic or non-automatic generators to effect the emptying suddenly by jerks, thus making certain that a quantity of lime sludge flows out before opening the water valve. After each opening replace with clean water and repeat. In this way, effective cleaning takes place at the time of emptying.

In water to carbide, dipping or immersion generators it is sufficient to throw a small quantity of water on the chamber farthest from the generator door just at the moment the generator is to be closed. This produces enough gas to replace the air in the generating chamber.

General Precautions.—In case of defective working or sudden failure it is absolutely necessary to avoid going near the generator with a naked light or any incandescent body, more especially if the odor of acetylene is present.

In the case of all repairs which have to be made to the plant in which a flame of any kind is to be used, it is essential to thoroughly remove all gas or mixtures of gas and air from the various parts of the apparatus. Remember that mixtures of 10 parts of acetylene to 90 of air are highly explosive; consequently, it is necessary to remove all traces of acetylene. All parts which are not easily gotten at can only be thoroughly cleaned by thorough rinsing repeated two or three times.

Access and working of the generator should be forbidden to all persons who are not charged with its making. A summary of the working instructions, both for the interior and exterior, and necessary precautions, should be provided.

Acetylene Light.—Acetylene constitutes a good method of lighting for work shops. Advantage can be taken of the generating plant and piping. The

Figure 25.—Jet Burner

piping and details required are exactly the same as for coal gas.

In cases of general lighting, incandescent burners are used where there is not too much risk of the mantles being deteriorated by shocks, dust, etc. Those who

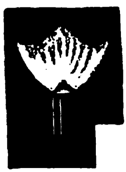

Figure 26.—Fish-tail Burner

use autogenous welding should not ignore the fact that acetylene is good for lighting, superior in many cases to coal gas, electricity, and in many cases more economical.

Figures 25, 26 and 27 show different styles of burners.

DISSOLVED ACETYLENE

It has already been noted that compressed acetylene, under the influence of heat or shock, is liable to decompose with violent explosions. Liquefied acetylene possesses these disadvantages to an even greater degree. Severel years ago inventors suggested making use of the solubility of acetylene in liquids in order to store the gas in portable form. To obtain a great solubility the acetylene must be highly com-

Fig. 27.—Fish-tail Burner, Impinging Type

pressed, and the properties of the gas in the dissolved state alter.

Acetylene Dissolved in Acetone.—Acetone is the most satisfactory liquid for dissolving acetylene gas. Acetone is a colorless liquid with an ethereal odor. It boils at 56° Cent. (132.8° Fahr.). One pint of acetone weighs approximately 1 lb.

The coefficient of solubility in acetone varies considerably with the temperature. Berthelot and Vieille have shown that a vessel containing half the volume of acetylene at an absolute pressure of 16.17 atmospheres and 2.8° Cent. (37° Fahr.) rises to 33.21 atmospheres at 50.5° Cent. (122.9° Fahr.). Under ordinary con-

ditions of use and working, the initial pressure is increased approximately one-thirtieth for each degree Centigrade rise of temperature.

The presence of water in acetone diminishes the coefficient of solubility. It is therefore necessary to use the purest acetone and to introduce the acetylene perfectly dry. Up to a pressure of 20 atmospheres to the square inch a solution of acetylene in acetone is quite stable.

Porous Materials.—However, the decomposition of the gas under pressure is still possible, filling the space between the liquid and the vessel and therefore the process is not industrially applicable.

All these disadvantages have been overcome by an improved method which consists of completely filling the cylinders with a porous material and then saturating it with acetone. Numerous experiments have shown that up to a pressure of 515 pounds per square inch this method is quite non-explosive, not only the solution, but also the liberated gas. The decomposition provoked at any one point in the cylinder can travel only a very short distance, producing an increase of pressure scarcely equal to the original pressure. In addition the porous material has the advantage of preventing any possible flowing of the liquid. It also facilitates dissolution of the gas and the phenomena of supersaturation.

A number of researches have been made on the composition of porous materials suitable for filling the cylinders of dissolved acetylene and numerous patents have been secured. The material is introduced in the form of a paste and the cylinders are then thoroughly dried by baking from fifteen days to three weeks.

Cylinders of Dissolved Acetylene.—The cylinders

are made from steel plate, often by means of autogenous welding. These cylinders are completely filled with porous material saturated with acetone to such a degree as to render them non-explosive. The porous material completely absorbs the acetone, so that it is impossible for the acetone to run out, no matter in what position the cylinder may be placed.

These cylinders are tested at a pressure several

Figure 28.—Cylinder of Dissolved Acetylene

times that to which the vessel will be subjected while in use. The necessity for renewing the porous material may be ascertained by testing the cylinders. For the purpose of dissolved acetylene, the gas is prepared in a generator under the best possible conditions. It is chemically purified and conveyed to a gasometer for cooling. The gas is then compressed into the cylinders containing the porous material saturated with acetone.

Contents of the Cylinders.—The volume of the cylinders varies, the cylinders usually employed for welding containing from 100 to 200 cubic feet of gas. As a general rule one cubic foot of porous material at a pressure of 150 lbs. per square inch will carry 100 cubic feet of gas.

The nominal capacity is only approximate as the dimensions of the cylinders and the weight of acetone which the cylinder contains varies. Moreover, the solubility in acetone varies with the temperature, so that the pressure gauge gives different readings according to whether the cylinder is warm or cold.

The only accurate test to verify the contents of the bottle under pressure is to weigh the bottle (1) charged with acetylene; (2) empty of acetylene. The difference gives the weight of acetylene used.

One cubic foot of acetylene weighs 0.074 lb. and 1 pound occupies a space of 13.6 cubic feet. Therefore, to obtain the net volume of gas in the cylinder, multiply the difference in weight when full and empty by 13.6. As an example let the weight of the full cylinder be 102½ lbs. and the weight empty be 95 lbs. The difference is 7½ lbs., which multiplied by 13.6 gives 102 cubic feet as the actual contents at 32° Fahr. The volume at normal temperatures would be increased above this value.

Use of Cylinders.—The cylinders of dissolved acetylene are provided with a valve opened with a detachable key. The valve fitting carries a thread for attaching the reducing valve to the cylinder. The use of a reducing valve is necessary for two reasons. (1) It is possible to know the pressure at any time, and (2) the amount of pressure may be regulated to the best point.

Advantages of Dissolved Acetylene.—The use of dissolved acetylene for autogenous welding has many advantages, among which are:

(1) No generating apparatus and accessories required.

(2) Portability.

(3) Use of high pressure blowpipes possible.

(4) Perfectly pure acetylene.

These qualities are so important that dissolved acetylene would always be used were it not for the fact that its cost is much higher.

On the contrary, the use of dissolved acetylene is always to be adopted where the cost of gas does not enter into the question, such as certain repairing jobs in shipyards, that is, outside workshops where, naturally, cylinders are more convenient than fixed or portable plant. In the case of the repairs to boilers and others which require perfect welds and which cannot be carried out in the work shop, the use of dissolved acetylene should be insisted on for the reason that small portable plants cannot supply the gas under as good conditions of purity, pressure, etc.

Manipulations and Precautions.—The cylinders of dissolved acetylene can be manipulated without any special precautions. The welder simply avoids their deterioration by violent shocks, falls, etc. The part which supports the valve should be particularly looked after.

The dissolved acetylene cylinders are not affected by lowering of temperature, therefore one can leave them exposed to cold in all seasons and in all countries. On the contrary, one should avoid leaving them in a heated atmosphere.

Care should be taken that there is no leak between

the valve and the reducing valve or in the reducing valve itself; all flames on the bottle, or in its neighborhood, should be extinguished as soon as possible; and the valve of the bottle should be closed after using. Lastly, the usual necessary precautions should be taken in the case of gases and inflammable vapors.

CHAPTER VI

OXY-ACETYLENE TORCHES

The oxy-acetylene blowpipe, or torch, intended for autogenous welding is an instrument of precision, yet extremely simple, of light weight and easy to handle. It mixes the oxygen and acetylene in just the right proportions. Figure 29 is a sectional view showing the general principles on which the torch operates. The mixture escapes through the exit nozzle and, upon

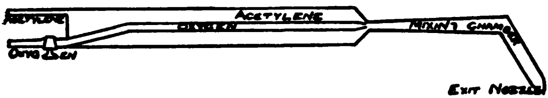

Figure 29.—Section of Oxy-acetylene Blowpipe

being lighted, produces a flame which is steady and of suitable dimensions for the purpose of welding.

As shown in Figure 29, the torch usually consists of a central body or handle, at one end of which the two gases enter, and at the other end of which is the mixing chamber which bends toward the nozzle. For ease of manipulation during welding the torch is bent at the nozzle and to an angle suitable for directing and observing the flame and its action.

According to the pattern and consumption of gas the lengths of blowpipes vary from 1 to 2½ feet and their weights range from 1 to 4½ pounds. They are generally made of brass while the nozzle or tip is made of red copper. They are made in various capacities corresponding to an hourly use of from 1 to 100

cubic feet of acetylene and appropriate for welding metals of all thicknesses.

Requirements.—The blowpipe should be as safe as it can possibly be made even in the hands of careless or unskilled operators. It should be simple, easily directed and should supply a steady flame. The consumption of acetylene and oxygen should be as nearly alike as possible.

These conditions are much more difficult to realize than appears, especially in the case of torches in which the acetylene is admitted at the pressure of generation; that is to say, practically no pressure.

The chief difficulty to be overcome is to obtain the necessary stability of flame. The velocity of propagation of the flame in the case of a mixture of oxygen and acetylene is about 330 feet per second. It is therefore necessary, in order to avoid the striking back of the flame, that the velocity of the mixture at the exit should be of the same value, or at least such that it constantly prevents the return of the flame to the interior.

Of course with the oxygen being stored under great pressure it is always possible to obtain a high velocity through the nozzle, but for reasons which it would take too long to explain here, the proper working of the blowpipe requires the oxygen under the most feeble pressure possible. This pressure is almost entirely used in aspirating the acetylene and insuring a sufficient exit velocity to the gas. The arrangement necessary to obtain this demands serious study.

The intimate mixture of the gases should be perfectly accomplished before their escape from the blowpipe. This consideration, which it is so important to obtain, is difficult to realize, because it is necessary to

avoid too much loss of pressure, which would require an increase in the pressure of the oxygen in order to regain the velocity through the nozzle which is necessary for the stability of the flame. The prevention of the return of the flame into the mixing chamber, which return is made easier as the torch heats up and as sparks fly around the nozzle, requires serious study.

Lastly, a large number of details merit attention, as for instance, the construction of the nozzle, ease of manipulation, cross sections of the several parts, ease of taking to pieces and reassembling, and, in fact, a torch which appears such a common article requires such precision in construction that it is only to be undertaken by specialists in the subject. The working and yield of different blowpipes can be compared by the stability of the flame, consumption of oxygen, etc. It is necessary to leave to specialists and experts the care and construction and even the repair of blowpipes, because the economy and good results of welding depend more on this than is generally thought.

Classification.—Oxy-acetylene blowpipes vary according to the pressure of acetylene, as we know that oxygen can be used without limit of pressure.

Blowpipes can be divided into three principal classes:—

(1) Blowpipes for high pressure acetylene.
(2) Blowpipes for medium pressure acetylene.
(3) Blowpipes for low pressure acetylene.

The meaning of the terms, high, medium and low pressure is as follows: high pressure implies more than 15 pounds to the square inch; medium pressure implies not more than 15 pounds per square inch; low pressure applies to systems using not to exceed 1 pound per square inch.

The delivery and power of the torch may be varied in high and medium pressure types by simply changing the nozzle or by regulating the openings which admit the gas. In low pressure the delivery is fixed because there is a suitable oxygen injector and nozzle for each case.

Low pressure blowpipes have been made which by the changing of a portion containing the nozzle, injector and mixing chamber, can be made to furnish different powers. This makes:—

(a) Torches for low pressure acetylene with fixed delivery; and (b) torches for low pressure acetylene with variable delivery.

Lastly, low pressure torches have been designed for variable delivery by regulating the oxygen injector according to the size of the nozzle, this being accomplished by means of devices for reducing the section through which the gas flows. These latter may be called torches for low pressure acetylene with oxygen regulator. It should be noted that blowpipes constructed for using acetylene at low pressure can also work with medium or high pressure acetylene by reducing proportionately the pressure of the oxygen. On the other hand, blowpipes for medium and high pressures cannot be used for low pressure acetylene.

Torches for High Pressure Acetylene.—These work with practically equal pressures of oxygen and acetylene, which makes their construction quite simple. The gases arrive by different tubes, one generally surrounding the other in the torch, and are intimately mixed in the tubes while being carried to the nozzle. The regulation is obtained by valves placed on the torch or by the reducing valves at the cylinders.

The acetylene and oxygen being used at practically

the same pressures, there cannot be a return of one gas into the tube used by the other. To prevent the flame from running back toward the source of acetylene, a screen of porous material is interposed immediately after entering the blowpipe. This allows the gas to pass through easily, but prevents passage of flame. The torch shown in Figure 30 shows this screen

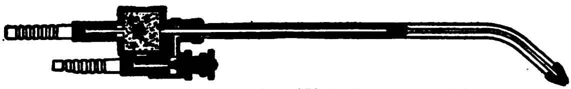

Figure 30.—Section of a High Pressure Blowpipe

made of aluminum shavings, also the valve for regulating the oxygen with the hand holding the torch.

In order to vary the power of the flame it is only necessary to change the nozzle. These are made in various sizes for different deliveries, Figure 31 showing a torch with several nozzles. Having selected the proper nozzle size it is only necessary to regulate the admission of the gases.

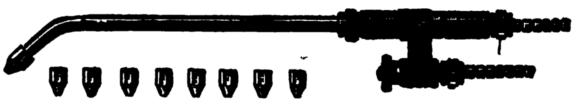

Figure 31.—Blowpipe for High Pressure, with Nozzles

If the gas issues from the nozzle faster than the speed at which this form of flame can travel, stable combustion cannot take place directly at the nozzle tip. Normal working of the flame takes place between fairly fixed limits of pressure which are easily maintained by the reducing valves. These pressures increase with the power of the torch, being always sufficient to approximately equal the speed of the flame.

Torches for Medium Pressure Acetylene.—Acetylene cannot be obtained industrially from generators at a sufficiently high pressure to use the blowpipes that have just been described; therefore, the best that can be done is to store the acetylene in gasometers having a pressure from 40 to 80 inches of water. Thus used, the acetylene does not require a much higher pressure of oxygen to give the mixture sufficient velocity.

An injector through which the oxygen escapes at a pressure slightly in excess of the acetylene is sufficient to give the necessary speed.

The injector nozzle of the oxygen remains the same whatever be the delivery of the blowpipe nozzle. It is only necessary to change the blowpipe nozzle to vary the power of the flame. The regulation is done by the cock controlling the gas or by the reducing valve on the oxygen bottle.

The principle of blowpipes for medium pressure is almost the same as for blowpipes using dissolved acetylene, except that the oxygen is used at a slightly higher pressure than the acetylene, which necessitates a slight modification in the arrangement.

Torches for Low Pressure Acetylene and Fixed Delivery.—The majority of acetylene generators deliver the gas at a pressure but little above the atmosphere. In order to obtain sufficient velocity at the nozzle, which is necessary for proper working, the oxygen must be used at a comparatively high pressure.

This meeting of the two gases in the torch, one at high speed and the other at low speed and pressure, requires special devices. In order that the mixture may take place, the acetylene must flow into a tube while the oxygen is rushing into the same tube at a

high speed. This results in the acetylene being sucked in by the oxygen. The higher the pressure of the acetylene the less effort will be required from the oxygen and *vice versa.*

Injector Action.—The suction of acetylene by the oxygen is produced by a device known as the injector. This works on the same principle as a steam injector, except that oxygen is used in place of steam.

The injector nozzle opens in a conical portion, where it draws in the combustible gas. The mixed gases are then ejected through an expansion chamber

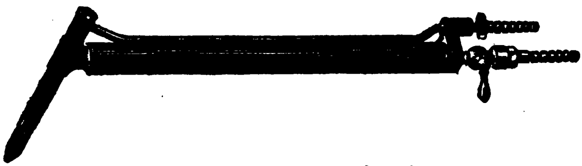

Figure 32.—Fouché Blowpipe

where the velocity is reduced to a suitable value. The proportions and arrangements of the various details have to be carefully worked out for each case.

It is clear that the delivery of oxygen being fixed by the size of the injector orifice, the power of the blowpipe is invariable in these limits, and in practice variation of pressure clearly means bad working.

Therefore, according to the number of powers of flame required, one should possess blowpipes, generally 5 to 10, for obtaining the whole range of deliveries; that is to say, from 1.75 to 2.65 cubic feet per hour to 70 to 90 cubic feet.

The orifice at the nozzle of the blowpipe for low pressure acetylene is designed according to the delivery of the injector when using the oxygen at a

pressure for which it has been designed. It is therefore essential that it be neither reduced nor enlarged.

The first inventors of low pressure acetylene blow-

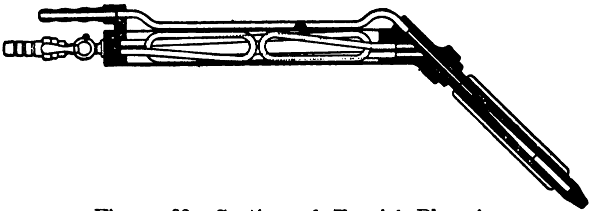

Figure 33.—Section of Fouché Blowpipe

pipes strongly feared the striking back of the flame into the tube containing the acetylene, as for example when the exit of the nozzle became obstructed. In

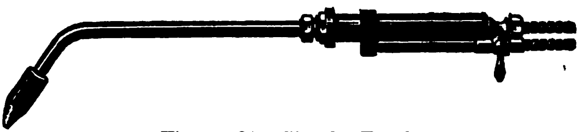

Figure 34.—Simple Torch

order to avoid this they invented many ingenious devices which are now known not to be indispensable, since the tube which brings the acetylene from the

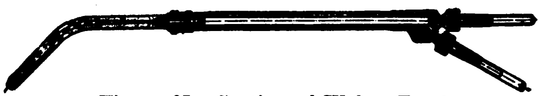

Figure 35.—Section of Weber Torch

cock of the blowpipe to the injector arrangement does not offer a sufficient explosive capacity, and a safety arrangement placed at the extremity of the acetylene piping prevents the passage of the oxygen into the latter.

A good idea of the many low pressure acetylene torches for fixed delivery and their construction can be had by a study of Figures 33 to 38.

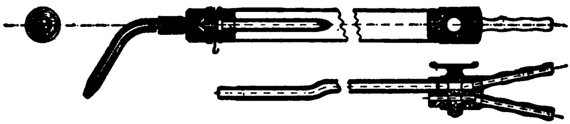

Figure 36.—Section of Columbia Blowpipe

Torches for Low Pressure Acetylene and Variable Delivery.—In torches of fixed delivery, if it is a question of making the power variable, it would be neces-

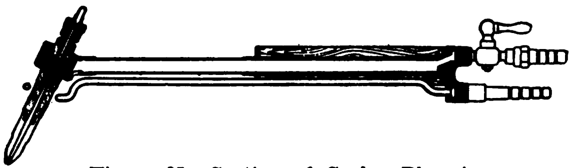

Figure 37.—Section of Cyclop Blowpipe

sary to provide for the simultaneous changing of the oxygen injector, the mixing chamber and the nozzle.

A type of variable delivery torch has been recently

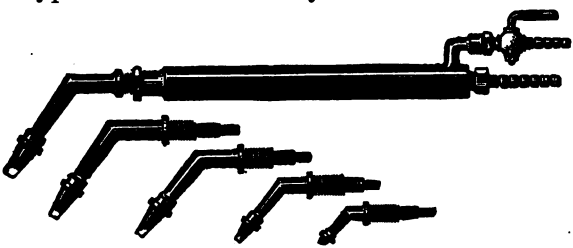

Figure 38.—Blowpipe with Interchangeable Heads

invented and has attained success. The inventor of the oxygen injector found that variable action might be secured by means of a needle valve controlling the

opening. This principle has been used by placing a nozzle suited for the required delivery on the torch and then adjusting the injector needle valve to this nozzle and delivery. By so doing one torch of this pattern can be made to furnish a large variety of

Figure 39.—Picard Blowpipe with the Oxygen Regulator

flames. This regulation of the oxygen is made by a small milled wheel controlling the needle valve so that the valve may be almost completely closed or entirely opened.

In order to obtain good results, the details and the regulator must be well made. The oxygen enters the

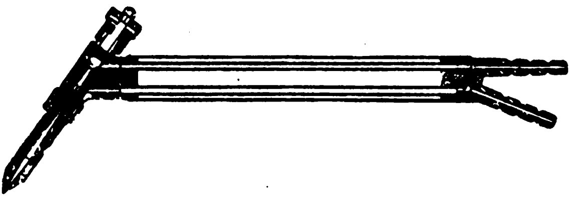

Figure 40.—Section of Essential Details of Picard Blowpipe

injector chamber in an annular jet and the suction of acetylene and mixing of the gases takes place as in the types previously described. Final regulation of the flame by the oxygen regulator is preferable.

This type of torch offers advantages over other systems of low pressure, although good construction and

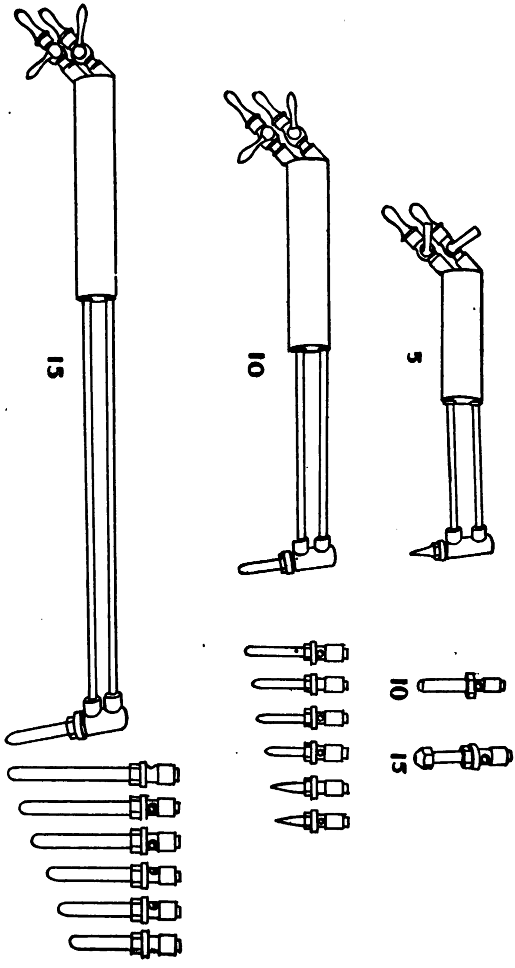

Figure 41.—Three Sizes of Torches, with Tips

perfect regulation are indispensable, while its handling and maintenance are quite difficult without practice.

Figure 41 shows three different sizes of torches. The number 5 torch is designed especially for jewelers' work and thin sheet steel welding. It is 11 inches in

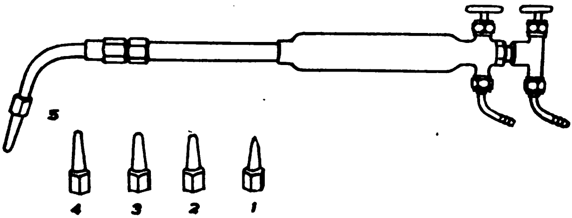

Figure 42.—Cox Welding Torch (No. 1)

length and weighs 19 ounces. The tips for the number 10 torch are interchangeable with the number 5. The number 10 torch is adapted for general use on light and medium heavy work. It has six tips and its length is 16 inches with a weight of 23 ounces.

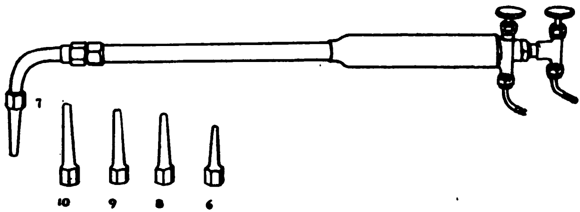

Figure 43.—Cox Welding Torch (No. 2)

The number 15 torch is designed for heavy work, being 25 inches in length, permitting the operator to stand away from the heat of the metal being worked. These heavy tips are in two parts, the oxygen check being renewable.

Welding Torches.—Figures 42 and 43 show two

sizes of another welding torch. Still another type is shown in Figure 44 with four interchangeable tips, the function of each being as follows:—

No. 1. For heavy castings.
No. 2. Light castings and heavy sheet metal.
No. 3. Light sheet metal.
No. 4. Very light sheet metal and wire.

Manufacturers have perfected an extremely small

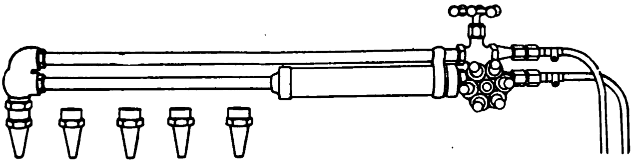

Figure 44.—Monarch Welding Torch

torch designed for jewelers and others needing a very hot, yet small and concentrated flame. It developes a neutral flame but little larger than a hair or pin point, yet having 5000° Fahr. of heat.

CHAPTER VII

CHARACTERISTICS OF WELDING TORCHES

The power or capacity of torches is based upon their hourly consumption of acetylene. The largest use up to 140 cubic feet per hour. Lower powers use from 3 to 25 feet per hour, or even less in some cases. The consumption of oxygen compared to that of acetylene should receive attention. Theoretically, the formation of the small welding jet requires exactly equal volumes of the two gases.

While this result may be approximately obtained in practice with high pressure torches, it is only approached with medium and low pressure outfits. All experiments on torches of high pressure show that the respective volumes of the gases are about equal provided the operators are competent.

Torches of medium pressure will give almost identical results if the pressure of the acetylene is kept practically constant and provided the oxygen pressure is not forced to attain too high velocity. All researches do not agree, but there is no very great difference between the volume of oxygen and that of acetylene used.

Torches for low pressure acetylene are those with which the most difficulty has been experienced in this respect of equal volumes. The oxygen, being used under high pressure, is difficult to mix with the acetylene while giving sufficient velocity. There is evidently an energetic mixing of the two gases, but not properly diffused and homogeneous, stream lines of each gas escaping at the nozzle.

This may be tested in various ways, for example, by contracting the exit from the mixing chamber or by increasing the pressure of the oxygen. In both cases the proportion of oxygen to acetylene is considerably increased. It might be concluded from this that a torch for low pressure acetylene consumes the least oxygen when the admission pressure of the latter is lowest and the mixing arrangements the best.

It should be remarked that in certain types of blowpipes the oxygen pressure to be used corresponds exactly with the arrangement of the mixing chamber. Change of section, abrupt bending, etc., can produce a loss of pressure. It is evidently necessary to find an equilibrium between these two factors, which are opposite. If the pressure of the oxygen is not raised too high, and the arrangement for mixing excellent, the result may be perfect.

In a series of experiments carried out with blowpipes for low pressure acetylene, the following results have been obtained which give the proportion between the volumes of the oxygen and of the acetylene, $\frac{O}{C_2H_2}$.

The letters A, B, C, etc., indicate the different types of blowpipe used.

Blowpipe A (23 cu. ft.), shortly after ignition 1.4, very warm 1.8.

Blowpipe B (8 cu. ft.), shortly after ignition 1.35, very warm 1.67.

Blowpipe C (15 cu. ft.), shortly after ignition 1.60, very warm 1.90.

Blowpipe D (20 cu. ft.), shortly after ignition 1.65, very warm 1.90.

Blowpipe F (23 cu. ft.), shortly after ignition 1.45, very warm 1.55.

Blowpipe F (30 cu. ft.), shortly after ignition 1.55, very warm 1.75.

These experiments were carried out with the best types of blowpipes, the admission pressure of the oxygen being that indicated by the makers in their catalogues, and the general regulation being according to their instructions.

The considerable increase in the consumption of oxygen on the blowpipe becoming heated should be noted. This only occurs in blowpipes using low pressure acetylene. The effect of expansion on the two gases admitted at different pressures is not the same, but it is relatively easy to obviate this disadvantage, as will be shown later in the section "Regulating the Flame."

Recent results of fifty industrial tests showed the exact volume of acetylene and oxygen consumed. The blowpipes used were of many types; the average delivery of acetylene was fixed at 12.3 cu. feet per hour, and the work to be executed lasted 30 to 40 minutes. The best proportion of oxygen to acetylene was 1.12, the average was 1.3 and the worst 1.9.

It was also shown that, with the same blowpipe used by two welders, one using oxygen at 28 pounds pressure and the other at 13 pounds, that the proportion in the first case was 1.83 and in the second 1.25, clearly showing the bad influence of excess pressure of oxygen on the consumption of that gas. It is important to note that the consumption of oxygen for a constant delivery of acetylene can vary greatly and can even double in volume, depending on the type of torch and the conditions of use. Not only is the oxygen consumed in excess of the theoretical amount a definite loss, but its presence in the flame burns the metal,

lowering the strength of the weld and making it brittle and porous. These considerations are very important from two viewpoints, economy and good work.

TABLE III.

COMPARATIVE CONSUMPTION OF OXYGEN AND ACETYLENE IN VARIOUS SIZE NOZZLES

Tips Used	Consumption of Oxygen per hr.	Consumption of Acetylene per hr.	Tips Used	Consumption of Oxygen per hr.	Consumption of Acetylene per hr.
1	3.50 ft.	3.45 ft.	6	28.00 ft.	24.00 ft.
2	5.26 ft.	4.25 ft.	7	37.70 ft.	33.00 ft.
3	9.00 ft.	8.27 ft.	8	47.74 ft.	41.84 ft.
4	14.25 ft.	12.00 ft.	9	65.81 ft.	56.72 ft.
5	21.00 ft.	17.26 ft.	10	93.97 ft.	82.47 ft.

Choice of a Torch.—The choice of torches, especially for low pressure, is a matter of importance. As has already been remarked, there are three different types of installations—high, medium and low pressure. The high pressure, using dissolved acetylene, is the simplest installation; it is portable, consisting of but two cylinders with their regulating valves, piping and the one torch which may be varied in power by changing nozzles. Using a good blowpipe with this system, welds are obtained under the best possible conditions.

On the other hand, acetylene dissolved in acetone is much dearer, costing often two to five times as much as the gas produced in generators, and this is the only fault of the system.

According to the kind of welds required, the use of dissolved acetylene installations should be given precedence where recommendable; that is, whether the nature of the work is of first importance, or the cost of

the same. The following are common examples where dissolved acetylene can be used advantageously:—Repairs on board ships and similar work in shipyards; garages for automobiles, mechanics' workshop, mills, etc., and in all cases where the application of autogenous welding is intermittent.

In certain large workshops where autogenous welding is used on a large scale it pays to manufacture dissolved acetylene on the spot, as this can be done without a large increase in price and permits of changing the place of welding, also using blowpipes for high pressure.

After compression the acetylene can be distributed under a pressure of 120 to 160 inches of water to the welding places by means of piping. Such installations should be carefully studied, and should not be used unless there is a very large consumption.

Medium Pressure.—The installations of medium pressure require a special acetylene generator to produce the gas at a pressure of 50 to 80 inches of water; also a hydraulic safety valve specially constructed for the pressure. It is then a question in this case of apparatus specially constructed for medium pressure: generator, hydraulic valve, blowpipe, and these cannot be used for other purposes. Manufacturers do not like to acquire installations which cannot be modified, perfected, or added to without applying to the firm that supplied it. On the other hand, the guarantees given are satisfactory.

The use of medium pressure gives results which are extremely favorable from the point of view we have studied above, and the installation of this type should be considered when choosing a system of welding.

Low Pressure.—The installations of low pressure

are those which are the most numerous; using the gas and generating it at a pressure of a few inches of water. We have stated previously the considerations which are useful in the choice of an acetylene generator, but the choice of the blowpipe opens up the question again, and the type of installation becomes a question of great importance.

Many types of low pressure acetylene blowpipes are offered to the purchaser, and good quality can be obtained in all types.

Let us note, first of all, that each blowpipe has its particular function and aim. Existing blowpipes can be fairly clearly classified according to their logical use, and corresponding to the particular ideas of their inventor.

There are torches with fixed delivery, others with variable delivery, the good and the bad, the light and the heavy, the long and the short. The choice depends, first of all, on the use which is going to be made of the torch. If it is to continually weld identical pieces of work, or if the welds require the same power of flame, then it is well to choose a torch of fixed delivery.

If, on the other hand, all kinds of welds are to be made, the torch should be of the variable delivery type. In indicating certain directions of choice between different types, it should be remembered that special conditions may vary. For instance, torches of fixed delivery are always to be preferred as being stronger, if the cost of a series of different sizes is not a serious matter. On the contrary, the small user, whose expenditure for tools is limited, should adopt the system of variable delivery, which offers him several torches in one.

Weight.—The weight of the torch becomes an import-

ant consideration in practical use. Welders say that the best torches are those that "feel best in the hand," but the choice depends upon the work to be done and the length of time the torch must be held. If it is a case of repair work which must be done quickly, then heaviness of the torch is not such a serious objection. On the other hand, if it is construction work in which the weld to be executed requires several hours without interruption, then lightness becomes an important quality of the torch.

Management.—The management and regulation should be considered in the light of whether the torch is to be used by experts or inexperienced men. All the different points heretofore enumerated should receive consideration owing to the fact that types approved in certain cases would be rejected in others. If search is made for the exact motives back of these rejections, it will be found that the questions of form, weight, solidity, etc., have been largely responsible.

Needless to say, all torches are not equally well constructed and regulated. The striking back of the flame into the mixing chamber, notably upon the nozzle becoming hot, is a serious defect because in order to avoid it, the welder increases the oxygen pressure. It is therefore an important quality of a blowpipe not to fire back or to light the interior, even after prolonged working.

To show that the consumption of the oxygen in proportion to that of the acetylene, is a point of considerable importance both from the point of view of economy and the execution of good welds, take, for example, the case of the small workshop using autogenous welding on a moderate scale, say, 2100 cubic feet of oxygen per month. Suppose a bad blowpipe is

used requiring 1.8 volumes of oxygen for 1 volume of acetylene, as is frequently the case. As the proportion of consumption of oxygen in good blowpipes only attains 1.2, the oxygen that should be used under these conditions is $\frac{2100 \times 1.2}{1.8} = 1400$ cubic feet. The loss is therefore 700 cubic feet, representing a loss of practically $25.00 per month and $300.00 per year, which can be easily saved by using a good blowpipe. Moreover, in addition to this loss, the excess of oxygen gives rise to bad welding.

This illustrates the importance, from economical considerations, of inquiring as to the relative proportions of oxygen and acetylene, seeing that excess of oxygen brings about bad welds. This factor is more important than the economy of the gas.

Therefore in choosing a blowpipe system from the point of view of the consumption of oxygen, as explained previously, one should stipulate a guarantee from the constructors; for example, the maximum proportion is 1.3, using the pressure of oxygen indicated. This would be quite sufficient for normal conditions of working of blowpipes.

Maintenance of Torches.—This consists in keeping in order the cocks and the joints of the movable pieces and the careful cleaning of the nozzle and tips from time to time.

This last operation is very delicate. In fact, one must take care not to enlarge the orifice of the nozzle, especially in the blowpipes for low pressure, because the slightest change in section produces derangement.

It is understood that for the same blowpipe the section of the nozzle corresponds to a determined flow of oxygen, but the orifice for the flowing of the oxygen

(the injector) remains unchanged, and any increase of the nozzle opening brings about a decrease of velocity at the exit, which provokes a return of the flame into the interior of the blowpipe.

The crusting of the nozzle by the oxides or particles of metal produces the following result: the delivery of oxygen being invariable and escaping under a greater pressure than the acetylene, the flame becomes oxodizing. When the hole through the nozzle becomes too small, it is the stronger one, viz., the oxygen, that

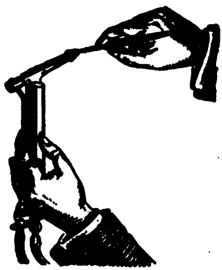

Figure 45.—The Scraping of the Nozzle Should Not Be Done with a Tool which Might Enlarge the Nozzle

gets through in preference to the acetylene. It is therefore necessary to watch that the nozzle does not become encrusted, but it is still more important not to enlarge it during cleaning.

The decrusting of the nozzle should be done by means of brass wire, excluding all tools such as files, and especially such remedies as rubbing the end of the nozzle on the bricks of the welding table or on metal. Any widening of the nozzle or increase of the exit passage will produce derangement of the torch. In some cases particles of dust are carried into the interior of the torch, causing a partial obstruction.

The working becomes affected owing to the difficulty of passage for the gas.

Some types contain a metal curtain which is supposed to keep back the dust, but this filter tends to become an obstruction itself in time, so the result is the same. The remedy for this condition is to take off the tubing and connect the nozzle of the torch directly to the oxygen cylinder through tubing, then

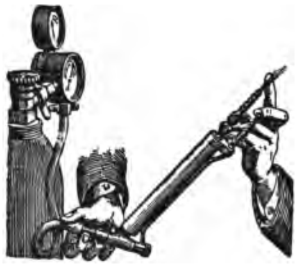

Figure 46.—Cleaning the Blowpipe by Means of Oxygen Under Pressure

raise the pressure of the gas by means of the reducing valve to about 10 lbs., and thus send the gas through the torch in an opposite direction to its usual flow. The acetylene cock on the torch being open, close the hole at which the oxygen usually enters with the finger (see Figure 46) so that the oxygen, under pressure, sweeps the passages clean. By playing on the opening with the finger the cleaning is greatly facilitated. The same thing can be done with the oxygen passages, although the obstruction of this tube and the injector is very rare.

If in the course of the work it is desired to cool a torch which back-fires on account of too great heating, care should be taken not to close completely the oxy-

gen supply, but allow it to flow sufficiently to prevent the entrance of water into the orifice of the nozzle. Great care should also be exercised to prevent grease or oil from getting into the interior of the torch, especially the oxygen tube, or the mixing chamber for the oxygen and acetylene.

No oiling is necessary, as any form of oil or grease will be oxidized by the oxygen gas and will cause gumming and sticking of the valves. Another thing to be avoided as much as possible is the taking of the torch to pieces, because in reassembling it generally requires adjustment and regulation which is the work of specialists. In cases of bad working and the impossibility of the repair being made by methods already indicated, the best procedure, and usually the most economical, is a speedy return of the instrument to its makers.

Torches should be treated as instruments of precision, ranged in good order, polished and ready for use.

CHAPTER VIII

WELDING INSTALLATIONS

An autogenous welding installation, especially one using acetylene at low pressure, comprises many other details and accessories in addition to acetylene generators, cylinders of oxygen and torches. There are the mains and service pipes from the generator to the welding place; the safety valve, which is indispensable to installations using low or medium pressure acetylene; the oxygen reducing valves; the flexible tubes carrying the gases to the torches; the welding tables and their accessories; and lastly, the special arrangements for certain kinds of work. The security and successful working of a welding installation depends in a large measure on a thorough understanding of these various details.

Acetylene Piping.—In the majority of autogenous welding installations now in operation, the pipes which convey the acetylene from the generator to the welding place are of too small section for the good working of the torches with large delivery. The result of this is a serious loss of pressure, thus tending to prevent the acetylene arriving in sufficient quantity and under normal pressure at the torch. The welder is thereby forced to increase the pressure of the oxygen in order to draw enough acetylene and often it will happen that air is drawn in through the discharge tube of the hydraulic valve. To obviate this difficulty, the cross section of the acetylene pipe should be in relation to the delivery and should provide for the maxi-

mum consumption for the largest torch that is to be used.

The loss of pressure for a predetermined delivery depends not only on the diameter of the pipe, but also on its length. In a good system of piping, this loss should not exceed 3/8 inch of water. If the gas leaves the generator or purifier at a pressure of 5 inches of water, for example, the pressure on entering the hydraulic valve should be 4 5/8 inches even during the working of the largest and most powerful torch. This favorable result is, however, rarely obtained, owing to the use of too small a pipe.

Following is an example of what is liable to occur with a pipe having an interior diameter of 5/8 inch. If the piping is 35 feet long, the delivery can attain 81 cubic feet per hour without the loss of pressure exceeding 3/8 inch of water; but for 50 feet it falls to 67 cubic feet; then for 100 feet it is 48 cubic feet; for 165 feet it is 35 cubic feet, and for 330 feet it is 26 cubic feet.

If a welding installation should deliver 50 cubic feet of acetylene per hour, a pipe of 5/8-inch diameter, which is sufficient for a length of 80 feet, should be increased to 11/16 inch for 165 feet, and to 13/16 inch for 260 feet.

The above examples are given to show that the diameter of the pipe should depend, not only on the maximum delivery that may be required from an installation, but also upon the length of the piping.

Table four will be of assistance in finding the necessary diameter of pipe according to the length and maximum hourly delivery. As the figures given in the table are obtained by theoretical calculation, it will be necessary in practice to take into account

unevenness of the pipes, leaky joints, etc., and to allow a slightly greater diameter than that which corresponds to the immediate future maximum consumption of the installation.

Table IV.

NUMBER OF CUBIC FEET OF ACETYLENE FLOWING PER HOUR IN A GIVEN DIAMETER AND LENGTH OF PIPING FOR A LOSS OF 0.4 INCH OF WATER PRESSURE

Length of Piping in Feet.	Diameter of Piping in Inches.							
	$\frac{13}{32}$	½	⅝	$\frac{23}{32}$	$\frac{25}{32}$	1	$1\frac{3}{16}$	1⅜
	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
35	27.6	53	84	111	152	...	...	...
50	20.5	40	67	92	119	...	...	...
65	18.4	35	58	79	103	179	...	...
80	16.3	31	52	68	91	160	...	...
100	14.8	28	48	65	83	146	250	...
130	12.7	25	41	56	73	126	218	...
165	11.3	22	37	50	64	112	193	262
200	10.6	20	34	46	5[illegible]	104	177	240
230	9.9	18	31	41	55	95	102	222
260	9.2	17.5	29	39	51	90	153	201
2[illegible]5	8.5	16.4	27	37	48	84	143	195
330	7.8	15.5	26	35	45	80	125	185

Connections.—The unions, joints or cocks should have an area of cross section equal to, or very little less than, that of the piping; this from the generator to the safety valve. A piping of appropriate diameter becomes useless if the gas is throttled at one or more points.

In the majority of workshops using autogenous welding, the acetylene piping consists of iron tubes

joined with unions, fixed to a wall or suspended. It is advisable to use galvanized piping, for the reason that with plain iron the gas, always a little moist, forms more or less rust, which comes off in a powder and may accumulate in certain parts.

Where the piping follows walls and there is no danger of crushing, the use of lead pipe is preferable for the following reasons: oxidation need not be feared; there is less danger of leakage; new branches can be connected without difficulty, and in case of removal due to increase of welding capacity, for example, the metal practically preserves its value.

Iron pipes, however, possess the advantage of being more rigid and are not so liable to be affected by shocks. Pipes or tubes of copper should not be used, especially if the acetylene has not been purified, owing to the danger of formation of acetylene of copper, which is spontaneously explosive. Brass is not subject to this disadvantage, but its use is hardly justifiable except for unions and cocks in the piping. The cocks should be carefully made and for large systems, cast iron cocks may be used with advantage.

The piping should be absolutely gas-tight and be tested after erection, and the tightness verified from time to time. The use of a flame in searching for leaks is dangerous. In the absence of a compression pump, and location by the hissing sound, the odor of the gas or the use of soap and water may be depended upon.

Safety Valves.—Mixtures of oxygen and combustible gases being explosive in a high degree, all precautions should be taken to prevent their formation, especially when their ignition is produced very easily, as by the passage of the flame through wire gauze, small openings, etc. When acetylene is used under

pressure lower than that of the oxygen, which is the case in all installations comprising an acetylene generator, the oxygen can return in the acetylene tubes and piping and mix with the acetylene, even as far back as the generator. This is the case especially when there is a total or partial obstruction of the nozzle of the torch, and it is therefore indispensable to place in the acetylene piping, before the flexible tubes reach

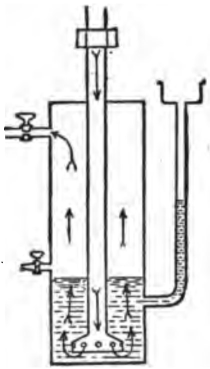

Figure 47.—Hydraulic Safety Valve During the Normal Working of the Blowpipe

the torch, a perfect device, capable of immediately arresting any return of the oxygen in the acetylene piping.

This is the very important function of the safety valve. It is not a question of avoiding the return of the flame, but to prevent the mixture of the two gases which would be explosive by the return of the flame or from any other cause. Another function of the safety valve is to direct any oxygen which returns in the direction of the acetylene, into the open air and

thus prevent its flowing further into the piping for this gas. Figures 47 and 48 are sectional elevations illustrating the action of the hydraulic safety valve.

The essential method of working is for the acetylene to bubble through a small height of water, but nevertheless sufficient for covering the tube leading to the exterior, this being between the surface of the water

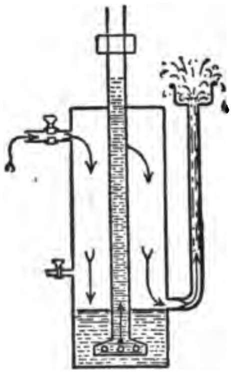

Figure 48.—The Hydraulic Valve at the Moment of the Return of the Oxygen

and the level of the escaping acetylene. If there is a return of oxygen, the pressure exerted on the surface of the water makes the liquid rise in the tube open to the air, forces it, if necessary, into the exterior, in such a way that this same tube eventually discharges the oxygen, the acetylene orifice meanwhile being protected by a seal of water.

The principle is not all that is required. It is further necessary that the construction should have been studied, and, in practice, one meets few hydraulic

valves established under normal conditions of safety and good working.

It is necessary, first of all, to avoid too large a gas capacity in the valve, because, in case of the return of the oxygen, and subsequent ignition, the explosion may be violent enough to break the valve and its parts. On the other hand, the diameter of the body should be sufficient that the level of the water will remain fairly constant, and the height great enough to avoid carrying drops of water to the outlet for the acetylene, and thence into the nozzle.

The large central tube leading the acetylene into the hydraulic valve should be of suitable cross section for the maximum delivery of the torch in order to avoid all loss of pressure. A tube whose diameter is too small is liable, when using a large torch, to cause a depression in the valve, which may produce a suction of air through the open tube. In ordinary welding practice the tube should have a minimum diameter of $\frac{1}{2}$ to $\frac{5}{8}$ inch.

The bottom of the tube leading the acetylene to the water in the valve, should have a larger cross section, as shown in figures 47 and 48, and be notched or pierced with small holes in order to avoid the pulsation of the gas by the ascension of large bubbles. The height of the water between the acetylene exit holes and the surface of the liquid, as given by the level cock, should be sufficient to allow the placing of the tube leading to the atmosphere without its being uncovered if the water level should be slightly lowered, and without the exit holes being uncovered in the event of the return of the oxygen. This takes into account the difference of the level which may follow the rising of the water under the effect of pressure in

the tube in which the gas arrives or in the one open to the atmosphere.

A depth of water ranging from 1¾ to 2 inches is usually sufficient. The tube leading to the outside should be located half way between the level of the water, as fixed by the cock, and the orifice, or the holes from which the acetylene bubbles. This tube should be arranged in such a manner that the bubbles of gas passing through the water will not enter it under ordinary working conditions. The cross section should be as small as possible to prevent the lowering in the valve under the pressure of the acetylene, but large enough to allow for the rapid discharge of the water, or gas, in case of the return of the oxygen.

A diameter of ⅜ inch should be sufficient in ordinary cases. The height of this outside tube depends essentially on the pressure of the acetylene, since the water rises in this tube as the pressure of the gas is increased. The height should be related to the change of level of the water in the valve, and should therefore be greater than that of a column of water corresponding to the greatest possible pressure that may be given by the acetylene generator.

Hydraulic valves are usually made for acetylene pressures varying from 4 to 5 inches of water, and the outside tube always has a height of 8 to 12 inches. For higher pressures it is necessary to increase this height, and to modify the valve in such a manner that the rising of the water in the tube should not lower too much the level in the valve.

The outside tube terminates in a chamber or funnel which serves for filling the valve with water. This is covered by a lid, which prevents the projection of water into the open in case of return.

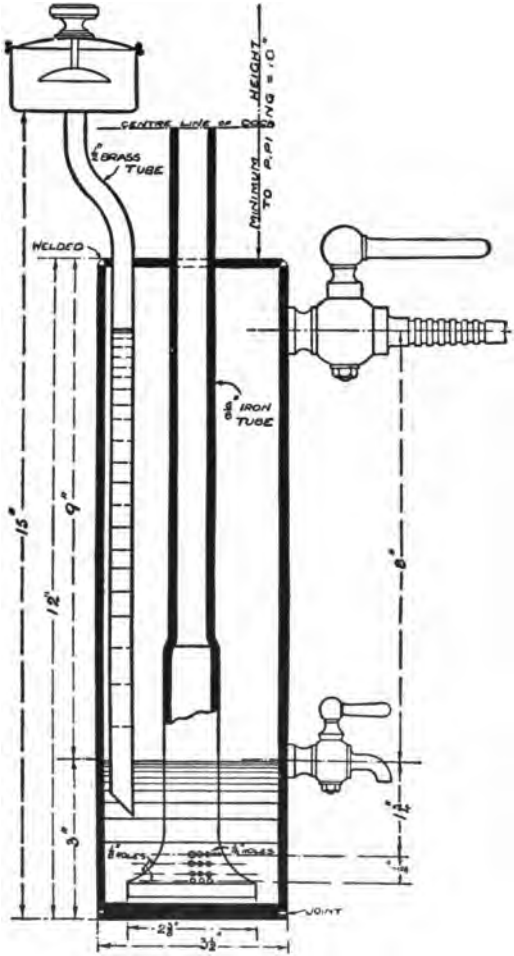

Figure 49.—Design of Hydraulic Valve

The valves should be made of plate or strong tubes. Where possible, the bottom should be jointed and not welded, so that in case of ignition after the return of the oxygen, the deflagration, if very strong, breaks the joint.

Figure 49 is a dimensioned drawing of the principle of the hydraulic valve. A good hydraulic valve does not get out of order. It is only necessary to verify the level of the water each day by means of the cock for this purpose. It is preferable that this operation should be done with the valve under working pressure, that is, with the acetylene arrival tube open. It is advisable from time to time to empty the water, which gets dirty and contains sediment capable of obstructing, more or less, the orifices for exit of the gas. The bottom, joined simply and hermetically sealed, makes this operation very easy, and enables one to examine at the same time the various details and see if these are in a good condition.

In order to avoid badly designed or badly constructed valves, so frequently met in practice, one should see that the safety arrangements satisfy the conditions we have just given.

The efficacy of such an apparatus should be absolute, and one should rigorously reject all arrangements based on the movement of a valve which obstructs the drawing of the acetylene when the pressure is reversed. Not only may such an arrangement not work, but its tightness is uncertain, even when, by a mechanical artifice, the oxygen may be discharged into the open.

One should therefore use the hydraulic safety valve, in which from a layer of water emerge two tubes, one for the entry of the gas, the other open to the exterior,

placed at different heights, constituting an absolute barrier to all return of the oxygen in the acetylene piping, without any possibility whatever of failure.

Oxygen Reducing Valves.—The storage of oxygen in steel cylinders under high pressure has been discussed in another chapter, and it has also been seen that the torches receive the gas under a much lower pressure, generally from 6 to 28 lbs. per square inch. The pressure of the oxygen must therefore be reduced and, at the same time, regulated in such a manner that it remains automatically constant no matter what the pressure may be in the oxygen cylinder. This result is obtained by using special apparatus adapted to the oxygen cylinders, called reducing valves or pressure regulators.

It is absolutely necessary to use an oxygen reducing valve in autogenous welding or the cutting of metals. In fact it is important to use the oxygen under a pressure automatically regulated and to know at any moment the value of this pressure. Reliable reducing valves are delicate instruments, but with correct ideas and proper care, it is easy to keep them in perfect working condition. There are a number of reliable types, which, while they may differ considerably in construction, all work on the same principle.

Referring to Figure 50, the oxygen arrives from the cylinder by way of a straight passage, passes through a filter designed to retain any dust, transmits its pressure to a gauge placed in connection with the passage, and which indicates the pressure in the cylinder at any moment. From the filter the oxygen passes into the principal part of the instrument, which is the automatic pressure reducer. The reducing valve comprises a mechanism for opening and closing the gas passage

by an ebonite seating controlled by a lever, the lever in turn being controlled by a diaphragm and the diaphragm being more or less deflected by the pressure.

A spring arrangement, regulated from the exterior, opposes the deflection of the diaphragm, and serves to regulate the pressure to that required, this pressure being indicated by a second gauge, termed the reducer

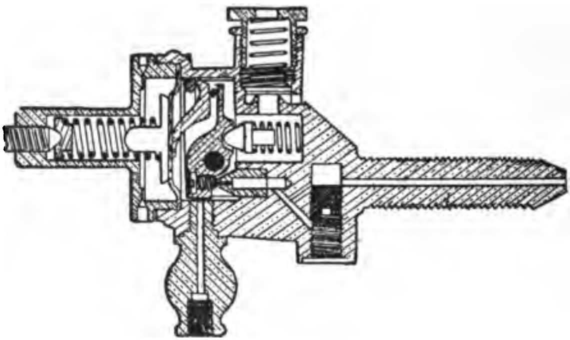

Figure 50.—Section of Reducing Valve, Showing Details

gauge, which the welder consults in regulating the flame.

The working of the apparatus is as follows: The gas presses against the elastic diaphragm until the required and predetermined pressure is reached; the diaphragm is then deflected and moves the lever which controls the passage of the gas. If the pressure tends to fall, the diaphragm ceases to hold the lever, the small valve opening is opened and so on. In this manner an equilibrium is obtained which gives a constant pressure no matter what the delivery or what the pressure of the gas in the cylinder may be.

The regulation, as has already been explained, is

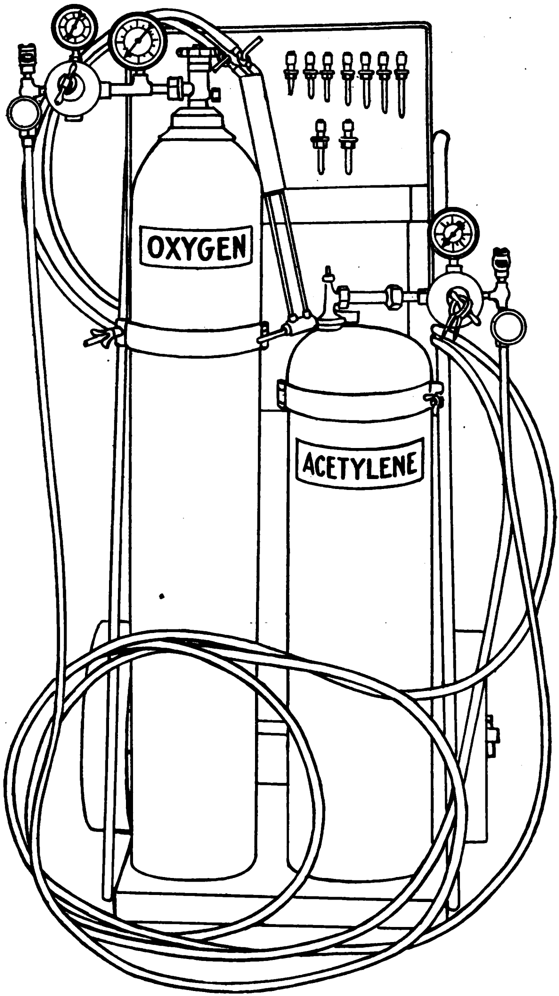

Figure 51.—Portable Welding Outfit

controlled from the exterior by pressure on the diaphragm in an opposite direction to that of the gas in such a manner that oxygen may be obtained under any desired pressure. A valve may communicate with the atmosphere from the reducing chamber, its function being to allow escape of the gas should bad working of the ebonite valve or other derangement allow the pressure to become too high.

Acetylene reducing valves are attached to the acetylene tanks for the purpose of reducing and controlling the pressure of the gas for welding. These act on the same principle as the oxygen valves, the only difference being in the material used in some of the interior parts.

Figure 51 shows a complete portable welding outfit. The reducing valves are shown attached to both the oxygen and acetylene tanks. Oxygen reducing valves are usually equipped with two gauges, one being for high pressure and showing the tank pressure. Figure 52 is an enlarged view of a reducing valve equipped with both high and low pressure gauges, the tank gauge reading to 3000 lbs. and the torch valve to 30 lbs.

Reducing valves are secured to the cylinders by means of a union screwed into the cylinder valve opening. Tightness is assured by simply tightening the ground faces. The operation of connecting is as follows:—

(1) Screw the movable part of the union as far back as possible so that the part fitted into the valve socket of the cylinder is left free.

(2) Place the reducing valve as shown in Figure 53 and enter the union into the valve socket. Now turn the nut until tight.

(3) Unscrew the nut slightly so as to be able to tilt the faces of the gauges a little forward or to one side, according to the type, then fasten all together with the hands and lastly complete the fastening with the aid of the reducing valve grasped in both hands and

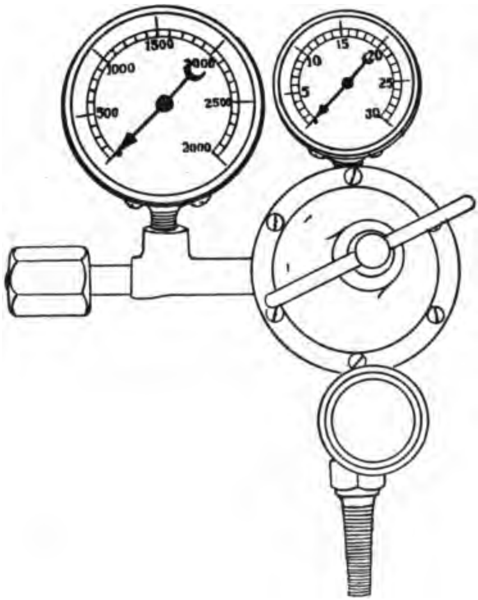

Figure 52.—Reducing Valve with High Pressure Gauge

turned with reasonable force. This should place the gauges where they can be easily seen. If the joint is not perfectly gas tight it may be further tightened by the union, but too much force should not be used.

Figure 54 shows the proper method of starting the flow of oxygen. The oxygen tank valve should always

be opened as slowly as possible and the reducing valve should previously have had its regulating screw turned out until entirely free. The outlets for the gas and the cocks should all be open through to the nozzle.

In this manner, heating by quick compression is practically avoided. These instructions are important for the safety of the welder and the preservation of the apparatus in a good working state, because sudden gusts of pressure on the diaphragm of the reducer produce derangement and quickly put it out of order.

Figure 53.—Fixing the Reducing Valve on the Oxygen Cylinder

After opening the cylinder it is only necessary to slowly screw up the regulating screw to obtain the required pressure. The outlet cock on the reducing valve should be opened wide, and should not be used for regulating the gas to the blowpipe.

Flexible Tubes and Connectors.—For the operation of the torch, the acetylene and oxygen are delivered to it through separate tubes, one coming from the hydraulic valve (or cylinder of acetylene if one is used), and the other from the oxygen reducing valve. These tubes may be of varying length, according to the degree of movement the welder will be required to

make. In many localities there is a certain minimum length of tubing and minimum distance that is allowed between the tanks and torch. This varies from 25 to 50 feet. The flexible tubes are made of rubber, covered with canvas, or into which canvas has been woven. They should be strong enough to resist several times the highest pressure used and not easily damaged by chafing, knocks, burns, etc.

Figure 54.—Opening Valve in the Oxygen Cylinder

In some places the regulations require that the tubes should be protected by an incombustible covering, and the tendency has been to use flexible metallic tubes or spiral tubes, sheathed with metal wire, etc. These types of flexible tubes are not to be recommended, because they deteriorate very easily, especially with sudden bends, or burns, such injuries not being easily noticed, which increases the danger.

The use of tubes of different diameters or differ-

ent colors according to whether they carry oxygen or acetylene has been recommended.

There should be standard connectors on the torch, the hydraulic valve and the reducing valves. This standardization is important because the details that go to make up a welding installation are frequently not of the same design or make, and when it is necessary to replace details with others having different size connectors, it becomes inconvenient and sometimes almost impossible to make good joints.

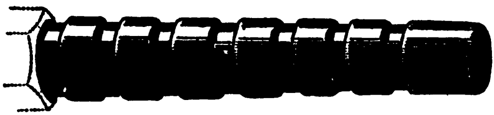

Figure 55.—Standard Connector

The connector for the rubber tube should be standard both in form and dimensions and should be the same for acetylene and oxygen. The form and dimensions given by the drawing, Figure 55, represents a good type. The interchangeability of the connector for the rubber and the thread of its union could remain optional. This standard connector has been adopted by the majority of the makers of torches and reducing valves and should be used for installations using 75 to 100 cubic feet of acetylene per hour.

The bore of connectors should be as large as possible, depending of course on the outside dimensions. The flexible tubes should have a cross section appropriate to the standard connector so that it can be simply pushed on without fear of splitting.

Some firms supply a fitting which constitutes a complete fastening attached to the rubber, which is cov-

ered by a wire network, and which is attached by means of a wing-nut.

The flexible tubes do not require any particular care beyond the prevention of burning, tearing, wear by friction, etc.; there should be no chafing in the interior, especially where it fits on the connectors, as the particles which become detached can obstruct the passages and organs of the blowpipe. Never grease the rubber or the connectors for the gases in order to make them

Figure 56.—Table for Welding Small Articles

fit each other easily; if necessary, they should be moistened with water.

Welding Table.—When the work to be welded is not too large it is best performed on a welding table, which should be made entirely of metal, except the covering, which should be of fire-bricks simply placed one against the other. Figure 56 shows one of the simplest arrangements, consisting of $\frac{3}{16}$-inch iron plates placed across two iron trestles and covered with fire brick.

The standard type of welding table is made in one or two hours by autogenous welding. Use stock size of angle iron 2¼ inches x 2¼ inches x ¼ inch. First

cut (with the blowpipe) 4 lengths of $2\frac{1}{4}$ feet for the legs of the table, then 4 lengths of $3\frac{1}{4}$ feet for the long side, and four lengths of $2\frac{1}{4}$ to $2\frac{1}{2}$ feet for the short side, the tables generally being rectangular.

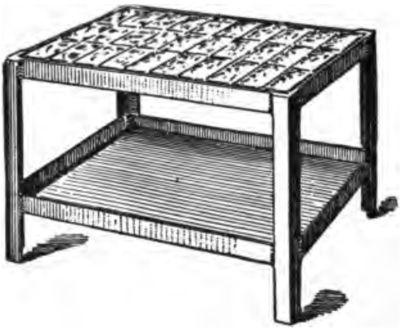

Figure 57.—Welding Table of Angle Iron Entirely Constructed with the Blowpipe

The joining of the twelve pieces of angle iron by autogenous welding is shown in Figures 58, 59 and 60. First weld the two frames, which must be cut at the ends to angles of 45° in order to fit the pieces to-

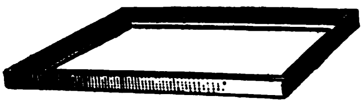

Figure 58.—Detail of Execution of Frames

gether. Next joint the two frames to the legs, one at the top and the other about two-thirds down, welding the first on the top and sides and the second simply on the sides. Next fix a plate in each of the two frames, covering the top one with fire bricks placed

side by side, (see Figure 57). The lower shelf serves as a place for tools, welding rod, etc.

Of course the dimensions here given can be varied

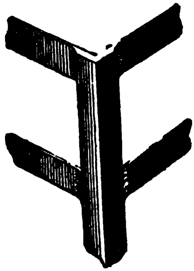

Figure 59.—Welding of the Frames of the Legs

to suit the requirements of the shop, for instance, the tables can be higher or lower, or much larger or longer as conditions and the nature of the case may demand.

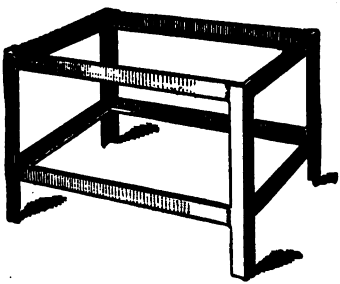

Figure 60.—Table Entirely Welded

Other types can be studied and constructed, which may suit the particular work of the welder much better than the rectangular form illustrated.

Tables can be made, similar to the one shown in

Figure 61, in which the top portion can be raised as required, inclined or turned—movements which may be extremely convenient for certain work. Tables can also be designed which contain a warming oven to preheat the parts to be worked. This may be made so

Figure 61.—Welding Table with Adjustable Top

that it can be taken apart easily and used for the repair of small pieces of cast iron, bronze, aluminum alloys and similar work which require preliminary heating and slow cooling.

Preparation of Welds.—A weld well prepared is half done, because the facility of execution depends in a large measure on the arrangements made by the welder in the preparation of the parts to be joined. In detail, this preparation varies notably with the nature of the metal, thickness of weld, and, above all,

the form and position of the parts to be welded; but it follows general rules which serve to indicate the methods to be applied in each particular case.

Beveling means cutting to form an angle, or slope, or chamfer. Beveling the edges to be welded is to facilitate the execution of the work and to make sure of melting the metal throughout the thickness of the

Figure 62.—Beveling for Pieces from 1/8 inch to 3/16 inch in Thickness, Angle of Bevel, 45°

weld. It offers equally the advantage of enlarging the line of joining, that is to say, it avoids the consequences of too great a localization of the defects, and, lastly, it allows the addition of a much greater quantity of metal of better quality and containing the required deoxidizing materials.

Figures 62 and 63 show examples of beveling for

Figure 63.—Beveling for Thickness Exceeding 3/16 inch, Angle of Bevel, 90°

various thickness of welds. From 1/8 to 3/16 inch a slightly open bevel is sufficient, the inclined surfaces forming an angle of 45° for example. For thicknesses of 3/16 inch and greater, the angle is increased to as much as 90°.

The beveling is obtained, according to the case, by chisel, file, or grinding machine; the cutting should

be regular, especially at the bottom, so as not to produce holes or excess thickness at the bottom of the bevel.

Rolled plates (tubes, etc.) offer, at their junction, a bevel which only requires retouching. In the joining of angle irons, plates at angles, etc., the beveling necessary for the good execution of the weld is also obtained without cutting, because the edges are arranged so as to practically form an angle of 90°. We shall see later that this method of joining is not always to be recommended.

The necessity for beveling exists, whatever the metal to be welded—steel, cast iron, copper, aluminum, etc. Separating the edges to be welded will not suffice for beveling. This practice should be avoided.

Adjusting.—The correct arrangement and securing of the parts to be joined so that during the welding they will remain perfectly in position is another important matter in the preparation and support of work to be welded. The angles of the bevel, or the edges to be joined should be held exactly at the same level. In cases of repairs to non-malleable pieces, as for instance, toothed wheels, parts of machines, etc., the adjustment before welding should be very carefully done. The maintaining in position of the parts on the table or otherwise is obtained by means of wedges, keys, clamps, iron wire, etc.

CHAPTER IX

PREHEATING AND ANNEALING

All welding installations and especially those concerned with the handling of articles in cast iron or aluminum, should be equipped with facilities for the preheating and slow cooling or annealing of these articles. The successful repair of cast iron, bronze, and alloys of aluminum requires, previous to the actual welding, careful preheating of the article, followed after the welding by a very slow cooling, in order to avoid the effects of expansion and contraction.

Furthermore, the annealing after welding tends to remove internal strains and it is always advisable to do this where there is no special difficulty standing in the way. Of course, the construction of a preheating furnace, may in some cases be rather complicated owing to the different sizes of articles to be handled.

Nevertheless, in those workshops that take orders for the repair of many articles of the same kind, for instance, cylinders and gear cases of automobiles, the installation of a permanent oven has great advantages as viewed from the point of economy in fuel and the regularity of preheating and slow cooling.

Figure 64 shows the design of one of these ovens which may also be arranged to serve the purposes of a table while doing the work. The hinged cover may be altered to accommodate various conditions in the work.

Precautions Relative to Expansion and Contraction.

—These phenomena, in the case of autogenous welding, are liable to produce the following defects: deformation, breaks or cracks and internal strains. If the whole of the piece to be welded can be raised to a high heat, somewhere near the melting point, and then uniformly cooled after welding, no serious results need be feared.

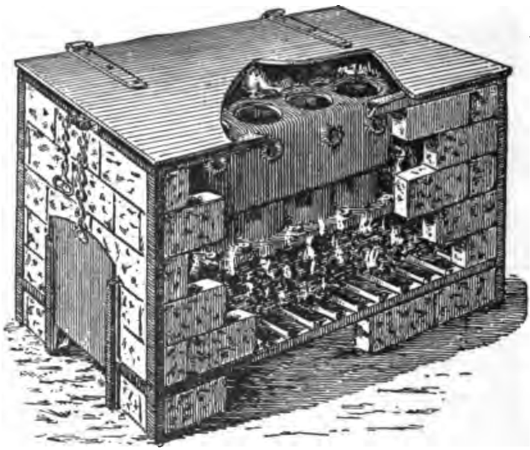

Figure 64.—Workshop Oven for the Repairing and Welding of Articles of Cast Iron and Aluminum

Castings should be heated in a convenient manner to a dull red heat, except engine or pump cylinders [if cylinders are heated to a red heat it is liable to warp them], and the torch applied when it is in this condition. It is important to remember that this sort of work should be done rather slowly. If the work is quite heavy, the outside will heat before the interior, and there will be considerable difference in

the amount of expansion. When such conditions exist, we are in danger of having breaks in cooling. The remedy is to heat slowly, so that, within or without, the distribution of heat may proceed in a uniform manner. Slow heating is especially to be advised where there is a combination of thin and thick parts, otherwise we may expect severe strains and perhaps breaks.

After completing the weld, great care should be taken in cooling the castings. Safe cooling is slow cooling. Cooling may be retarded by the free use of sheet asbestos as covers, or the castings may be buried or packed in hot ashes or sand. Apart from the preheating for reasons already explained, it is also very valuable as to time and cost of making the weld, which may be reduced from 30 to 50 per cent by previously heating the pieces to be welded.

In welding cast iron, such as automobile cylinders and machinery parts of similar character, it is necessary to preheat the part which is to be welded to a temperature which is slightly below a dull red heat, or to a higher heat, if there are no parts that will be injured by such heat. This heat should be applied gradually, and when the whole object has been sufficiently preheated, the welding can be done.

The furnace or muffle is built of fire brick to a suitable size for the particular part to be handled. A removable cover of asbestos or sheet metal is used. After the weld has been made the article should be heated again and allowed to cool gradually and evenly to prevent cracking and to make the material in the weld less hard and brittle.

As a general rule, it is possible to overcome the effects of local heating by foreseeing the manner in

which they will manifest themselves, and so controlling them to the extent that they have no bad results.

Expansion and contraction cannot be overcome by force; the phenomena manifest themselves whatever one does, and it is perfectly useless to try to oppose them. The method is to avoid or limit their consequences.

Figure 65 will serve to illustrate several methods of dealing with this important matter. Assume that the bar shown in the upper portion of the illustra-

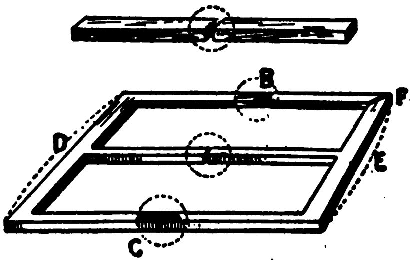

Figure 65

tion is to be welded at the spot designated by the dotted circle. No bad effects of expansion or contraction are to be feared when it is free to expand or contract. No precautions are necessary to overcome the expansion and contraction in this case. But suppose that the same bar, having the same break, is located, for example, in the middle of the frame shown in the lower portion of Figure 65, and must be welded. No bad effects of expansion need be feared, since, on heating to fusion the edges to be welded, the expansion takes place and the edges to be welded approach

each other, the metal in fusion offering practically no resistance to this expansion.

But the weld is completed, and the metal commences to cool and contract. Now the bar which was free to expand does not offer the same freedom to contraction, since the two extremities of the bar are fixed solidly to a frame which was not previously heated and consequently is unchanged.

If the metal is ductile, elastic, the contraction of the parts heated will not produce a break, but simply a deformation or strain corresponding to the linear value of the contraction. This would often be the case, for example, with mild steel. If the piece was of cast iron, cooling would probably produce a break in the welded portion.

A break will frequently occur in those metals which are ductile at ordinary temperatures, but whose strength when hot is extremely low, copper, for example; it takes place during cooling in that part which remains at the highest temperature.

The realization of welds in such metals is possible. All that is required is reflection and adjustment.

One could raise the whole piece to a high temperature before welding, and thus produce expansion in the entire mass, and in this way equal contraction. But, as a matter of fact, complete heating is not necessary. It is sufficient to heat, simultaneously with the operation of welding, the parts B and C of the frame and thus obtain equal expansion to that of the broken bar; then, on cooling, the contraction is of equal importance in the case of the two parallel bars and the repaired bar. Therefore there is no strain in the metal or break.

Suppose it were impossible to heat the frame at B

and C. Other methods are at the disposal of the welder; for example, a slight separation of the two bars D and E by bending separates the two edges to be welded. This done, proceed to weld, and at the end of the operation, that is, as soon as contraction commences, due to cooling, remove the keys, wedges, or screw jacks from between the sides D and E. The return of the bent bars to their original position annuls the effect of contraction in the welded bar, and thus welded it should be free from strains, deformations, or breaks.

Another method is, although the success depends upon the thickness of the metal, to cut the frame at F, execute the weld of the bar, and then weld at F, the effects of contraction being least to be feared at this part. Sometimes it is necessary to break a piece in order to repair it.

This example shows the importance which the welder should attach to foreseeing the effects of expansion and contraction during the execution of the weld and on cooling. And this is evidently part of the preparation, since it is not possible to guard against the consequences of these phenomena once the welding has commenced. The devices to be followed vary in each case.

Heating Agents.—The heating agent used in the ovens already mentioned is wood charcoal, or wood charcoal mixed with coke. Fuels of this type have many disadvantages. Their heat is generally badly utilized and imparted in a rather irregular manner to the articles to be repaired. Again, the residue of combustion can be deposited in the cracks or bevel; and lastly, the articles being generally welded while in the oven, the heat and smoke are an inconvenience

to the welder. Much more satisfactory results are obtained by the use of powerful burners in which benzine, gasoline, kerosene or heavy oils can be used. It is not economical to use the oxygen from the cylinders when a sufficient supply can just as easily be drawn from the air to serve these burners.

In some cases advantage can be taken of the large bunsen burners of acetylene which are made for industrial heating and which are arranged to suit the requirements of the welder. Figure 66 shows such an arrangement. It is often the case that the articles to be welded do not have to be preheated in an oven, but do require to be heated to a high temperature in the vicinity of the weld, and further, it is often desirable, after welding, to heat the line of the weld.

Fig. 66.—Group of Acetylene Bunsens for Preheating

Figures 67 and 68 show two styles of portable preheating and annealing burners adapted to this service. The heater shown in Figure 67 is to be preferred in

shops that are equipped with compressed air, since it can be operated under any pressure varying from 10

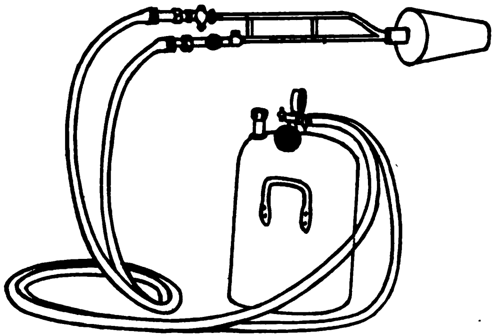

Fig. 67.—Portable Preheater and Annealer. Compressed Air Type

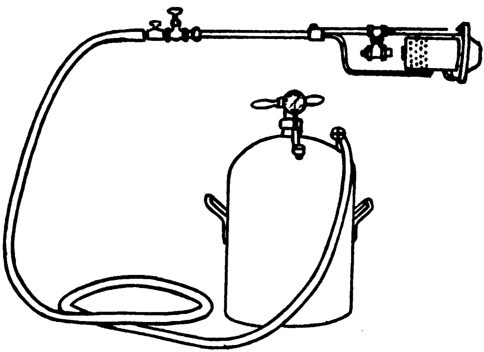

Fig. 68.—Portable Preheater and Annealing Device

to 120 lbs. Any grade of fuel oil, crude oil, kerosene, etc., is adapted for use in it. Table V gives sizes and other details relative to this device.

TABLE V.

No.	Capacity of tank	Length of hose	Oil consumption per hour	Air consumption cubic feet free air per minute	Shipping weight	Weight of burner
2	15 Gal.	24 ft.	3 Gal.	15	100 lbs.	10 lbs.
4	12 Gal.	24 ft.	2 Gal.	12	90 lbs.	6 lbs.
5	10 Gal.	24 ft.	1 Gal.	8	85 lbs.	3 lbs.

Figure 68 shows a portable preheater and annealing burner which is entirely independent and self contained, having a hand air pump built into the tank. This device is designed for field and shop work when compressed air is not available or convenient. It is intended for kerosene only, the flame being easily regulated as desired. Before operating this burner it is necessary to obtain 25 to 50 lbs. air pressure with the hand pump. The burner operates approximately two hours with a single pumping. Table VI gives capacities and other details.

TABLE VI.

No.	Capacity of Seamless tank	Length of hose	Oil consumption per hour	Shipping weight	Weight of burner
7	10 Gal.	12 ft.	1 Gal.	80 lbs.	5 lbs.
8	12 Gal.	12 ft.	2 Gal.	95 lbs.	6 lbs.
9	15 Gal.	12 ft.	3 Gal.	110 lbs.	8 lbs.

Manufacturers also make a special preheating torch for use in localities where both compressed air and illuminating gas are obtainable. This torch is so designed as to mix the gas and air in proportions to give a large hot flame.

To Restore Iron and Steel.—In welding iron and steel, after completion of the weld, bury the work in

ashes or lime until thoroughly cooled, then reheat the article again until it is red. Apply a magnet to the part welded. If the magnet is attracted to the article, turn on a little more heat until the magnet is no longer attracted. As soon as this occurs, discard the use of the magnet, but keep heating the article for about two minutes, then bury the piece again until thoroughly cold. This will restore the piece to the same condition as it was before the break. If the workman does not do this the grain of the metal will be coarse where the weld is, and will break more quickly than if it is restored as above. If the work is done as explained, the grain of the metal will be fine and will have its original strength and toughness.

Goggles.—Metals in fusion under the action of the torch emit extremely bright light which fatigues the eyes and prevents the welder following the course of the work. It is important therefore for him to wear special glasses, smoked or colored, so as to dim the brightness of the incandescent metals, protect his sight and enable him to follow the work properly. This precaution is absolutely indispensable and any welder who operates without glasses is courting serious trouble and early loss of ability to handle this work. These glasses also serve to protect the eyes from particles of oxide that are projected from the weld. It is a difficult matter to indicate the exact color of glasses to be used since this depends on the sight of the user and the nature of the work. The use of very large torches and those for cutting obviously requires very dark glasses and this rule also applies to certain fluxes which emit bright light. The glass should be sufficiently dark to prevent the eyes from becoming fatigued, but not dark enough to

strain the sight. The settings of the glass also differ. There are a number of different patterns to choose from, depending on the distance of the glass from the eye, the circulation of air around the eye, etc. For special work, goggles have been designed that protect the neighborhood of the eyes and the nose by means of a mask.

Torch Lighter.—A flame of some kind is necessary near the welder while he works for the purpose of lighting and re-lighting the torch. A small flame of acetylene or illuminating gas fixed to the wall is generally used. This is better than a candle because the gas flame is not easily extinguished by the torch.

Accessories.—Autogenous welding installations also contain certain accessories used by the welder. These accessories vary according to the work to be done, such as the tongs for moving the warm articles, wedges, keys, hammers and mallets, clamps, etc.; also vices, anvil and accompanying tools; water vessel, waste, etc.

For welds of great thickness, and for welding articles in or on the ovens, the welder should have gloves and a table covered with asbestos; also plates of the same material to protect him from the radiant heat. Lastly, there is the rack for the blowpipes and a shelf for the fluxes, welding rods, spare parts, etc. A card containing advice and practical hints should be placed by the side of every welding table.

CHAPTER X

OPERATING A WELDING INSTALLATION

Having studied at some length the gases used for obtaining autogenous welds, and also all the various apparatus and equipment required for a complete welding installation, it is now in order to deal with methods of operation.

Installations using acetylene at low pressure and medium pressure will first be taken up, after which methods of working with high pressure equipment, in which the acetylene generator is replaced by the cylinder of gas under pressure and reducing this pressure with the special valve instead of the hydraulic valve, will be discussed.

Testing the Plant.—If the plant has just been erected, or cleaned, or if it has been standing idle for some time, the first thing to do is to drive all the air out the piping and parts until a burner gives a normal light. The piping should be charged with gas right up to the cock opening into the hydraulic valve, and having been tested by methods previously described, should show no leakage. The oxygen cylinder, with all the water removed from within it, and the valve, with all the dust removed, are to be placed in position. The reducing valve is also placed in position, as already explained, and, if upon final test, there is no leakage, the work may proceed.

Selecting a Torch.—A torch of appropriate delivery for the work to be welded is chosen and connected by means of the flexible tubes to the reducing valve

on one hand and to the hydraulic valve on the other. Care should be exercised to avoid becoming confused regarding the tubes on the torch. The tube designed for acetylene generally differs from the other in having a cock which serves to regulate this gas.

Testing the Hydraulic Valve.—Having completed the attachment of the flexible tubes, it only remains to test the water level in the hydraulic valve, which should be done at each working point at least once a day according to the following method:

Open the gas cock leading to the hydraulic valve in order to put it under working pressure, then open the cock to gauge the level of the water. If any gas escapes, the water level is too low, and it is necessary to add more through the open tube; if only water escapes, then it is in excess, and should be allowed to escape until the gas bubbles of acetylene appear. The following method is more positive and more sure:—(1) Pour water into the open tube so that it is in excess; (2) charge the valve with gas; (3) take off the excess water by the gauge cock until the appearance of a stream of gases. The hydraulic valve being thus prepared to carry out its function, the installation is in starting order.

Starting.—In starting, proceed as follows:

(1) Open *very slowly,* that is, do not unscrew sharply, the valve of the oxygen cylinder; the regulator screw on the reducing valve being entirely free, and the outlet valve open, as previously explained (Fig. 54).

(2) Open fully the acetylene delivery cock on the hydraulic valve.

(3) Open fully the acetylene delivery cock on the blowpipe.

(4) Light the blowpipe and at the same time screw up the regulator on the reducing valve.

(5) Continue to screw up the regulator until the reduced pressure, as shown on the gauge, corresponds to the normal working of the blowpipe, which should be known.

At this moment the flame, which was at first sooty, still contains an excess of acetylene, which is shown by a streaky light about its center, in the extension of the exit nozzle.

The variable delivery blowpipes in which the orifice of the oxygen ejector is controlled by a needle valve are managed slightly differently; the regulating screw of the reducing valve is entirely closed, the reducing valve is then set to the pressure required, next light the acetylene and open the needle regulator progressively so as to obtain a slight excess of acetylene. Then go slightly backwards to obtain the normal flame.

Some welders regulate the reducing valve first, others first open the oxygen, then the acetylene, and afterwards light the blowpipe. There is nothing against these methods when the operator is experienced and knows thoroughly the details of the welding installation. As a general rule, it is better to work as we have indicated, free to give the various movements almost simultaneously.

REGULATING THE FLAME

The flame at first shows an excess of acetylene. Torches which show otherwise with a normal pressure of oxygen and with the acetylene fully open

are deranged or obstructed and should not be used in this condition unless it is known that the defect is one of obstruction in either the acetylene piping or the hydraulic valve. In either case it should be remedied as soon as possible.

With this excess of acetylene at starting, the flame

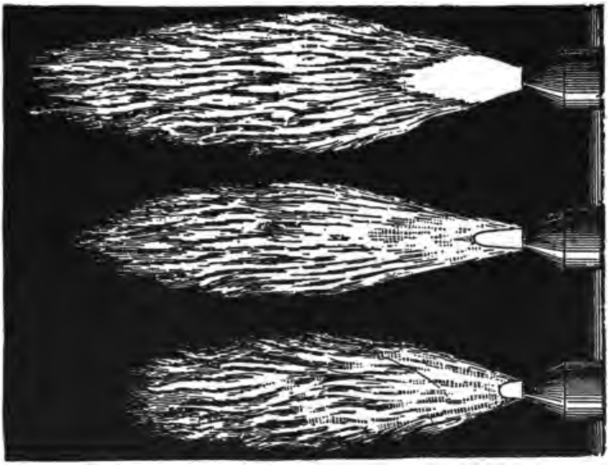

Figure 69.—Regulation of the Flame. Top Figure, Excess of Acetylene; Middle Figure, Normal Flame; Lower Figure, Excess of Oxygen

is what is called carbonizing. In order to render it normal, called neutral, it is necessary to close partially either the acetylene cock on the torch or the one at the exit from the hydraulic valve, but preferably the former. The streaky light disappears by degrees and its place is taken by a white halo, which is extinguished in turn as the small white jet in the center of the flame next the nozzle becomes more pronounced. This is a neutral flame.

If the acetylene is still further reduced, the white jet diminishes in size and the flame becomes oxidizing, that is, there is an excess of oxygen. Figure 69 shows clearly these three conditions of the flame and is self explanatory. It is evident that the flame can have either an excess of acetylene or an excess of oxygen, and either of these conditions must be carefully avoided in order to obtain good welds and economy in their execution.

The neutral flame is obtained by reducing, little by little, the excess of acetylene, but this reduction must be stopped at the instant all the white halo, previously referred to, has disappeared.

The flame is then characterized by a small violet-whitish jet of very clear outline. Its base is at the end of the nozzle, and for medium delivery blowpipes its length is only 1/4 inch to 1/2 inch. It is surrounded by a large bluish flame, in which the second phase of the combustion takes place. At the extremity of the white jet we obtain the highest temperature of the flame.

The regulation of the flame is in a way the regulation of this white jet. The white jet should be as large as possible, providing that its outline is very sharp, and that there is no whitish mantle round it.

This precise point must be carefully sought for, readjusting several times during the work to make sure of this point.

Management of the Torch.—It is very important that the flame should remain neutral, that is, normally regulated. The flow of the gas in the majority of torches for low pressure acetylene is modified by its heating. The acetylene expands, arrives at the mixing chamber in less quantity, and the flame

gradually becomes oxidizing. Some welders start with a slight excess of acetylene, a scarcely visible halo surrounding the white jet which disappears as the torch becomes heated. An excess of acetylene is to be preferred to an excess of oxygen, only, however, as a choice between two evils, neither being best for working.

A better method is to start with the flame neutral and remedy the variation after the torch has become heated. Good regulation is thus obtained with two or three adjustments, although several times during the weld an excess of acetylene should be produced and the flame then brought slowly back to the right point.

In making certain welds, the torch is liable to become too hot and in spite of all possible attention to adjustment the flame leaves much to be desired. One remedy for this condition is to plunge the nozzle into water with the flame extinguished and the oxygen turned on slightly so that the flowing of the gas opposes the entrance of the water into the orifice of the nozzle. On the other hand, the acetylene should always be closed in order to avoid the formation of an explosive mixture above the water, and the blowpipe should never be plunged in while lighted.

Defective regulation, bad condition of the blowpipe, too much heating of the nozzle, irregularity of the flame, projection of sparks can sometimes return the flame or tend to return the flame into the interior of the blowpipe.

This is indicated by sharp crackings, which in the case of large blowpipes sometimes produce a very loud noise. In the majority of cases the flame be-

comes normal again after these manifestations of the striking back into the interior; but if the detonations are renewed, it is best to remedy it by cooling the blowpipe, as we have explained, and cleaning the extremity of the nozzle. Certain welders find it convenient to increase the pressure of the oxygen; this will obviously prevent the return of the flame.

Sometimes there is a persistent flashing back and burning in the mixing chamber accompanied by a hissing noise, the neutral flame disappearing and its place being taken by one that is usually smaller, reddish and without power and from which black fumes issue. In such a case the gases should be cut off immediately because this heats the interior of the torch, incrusting it, and may destroy or damage some of the parts. Some welders simply bend the actey-lene tube, cutting off this gas and hold it closed until the internal burning has stopped, after which they release the tube and relight the flame by contact with the red hot metal. The safer method is to cut off both gases by the nearest cock.

Handling the Torch.—In proportion to the execution of the weld, that is to say, to the joining of the edges by melting the metal, the blowpipe must be moved forward very slowly and with great care in order to obtain a continuous and regular weld.

It is an advantage, of course, to give the blowpipe a movement such that the two edges to be welded are attacked by the flame in such a manner as to bring about simultaneous fusion. The movement, therefore, should be frequent and regular.

The best movement is to make the small white cone describe a circular movement, the diameter corresponding to the molten bath obtained, accord-

ing to the thickness to be welded, so that this movement, combined with the advancing one, gives a series of elliptical curves, the locus of their centers being in the direction of the line of welding.

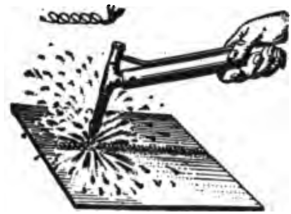

Figure 70.—Circular Movement of the Blowpipe During the Execution of Welds

One can also, especially for thick pieces, proceed in half-circles, or play the flame regularly from one side to the other, regulating the rapidity of the movement according to the melting and the bath

Figure 71.—Oscillatory Movement for the Execution of Welds of Great Thickness

of liquid metal obtained. The welding is done by pushing the torch and not by pulling it except in the cases where the two edges touch each other completely, and for thin pieces (tubes, for example), a

movement from side to side is indispensable. According to the metal, its thickness and shape, the welder should give a regular and careful movement. Figures 70 and 71 illustrate the different movements.

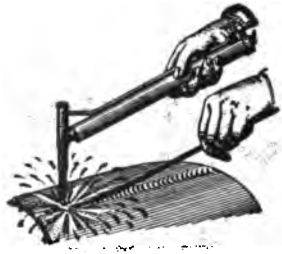

Figure 72.—Normal Holding of the Welding Rod

Position of the Welding Rod.—The welding rod is held and directed by the left hand of the welder. If it is a question of a thin flexible rod, it should be bent or curved so that the flexibility does not cause vibrations, or deviations at the end.

Figure 73.—Adding Metal from the Welding Rod

No definite instructions can be given with regard to the inclination; the direction depends on whether it is in the form of a rod or thin wire. The melting of the welding rod and the edges of the weld should

take place at the same time, so as to cause the two metals to alloy with each other immediately. If the welding rod metal flows between the edges of the weld before they are melted, the joint will be bad. It is then an adhesion, not a weld.

Acetylene Regulation, High Pressure Systems.—First, valve A (Figure 74) on the acetylene tank must gradually be opened a full turn. Turn the handle B on the acetylene regulator until the desired pressure shows on gauge C, which should be 20 lbs. for a number 5 nozzle and 15 lbs. for numbers 1, 2, 3 and 4.

Open the needle valve or cock D, then the torch valve E. The acetylene is now flowing at the regulated pressure through the torch. After securing the supply of oxygen as follows, the flame may be lighted.

Oxygen Regulation.—The following table gives the proper pressures:

No. 1 Nozzle Tip—10 to 12 lbs. of Oxygen.
No. 2 Nozzle Tip—12 to 14 lbs. of Oxygen.
No. 3 Nozzle Tip—14 to 16 lbs. of Oxygen.
No. 4 Nozzle Tip—16 to 18 lbs. of Oxygen.
No. 5 Nozzle Tip— 20 lbs. of Oxygen.

Open the oxygen cylinder valve F (Figure 74) gradually to a full turn or several turns. Turn handle G and regulate until pressure shows on gauge H according to the preceding table of pressures. Open the regulator needle valve I, then the torch valve J, allowing oxygen to pass into the torch and mix with the acetylene.

The flame may be lighted as the oxygen is being turned on or with only the acetylene flowing, but do not allow both gases to flow before lighting.

It is now necessary to regulate both oxygen and acetylene by the valves E and J until the nozzle

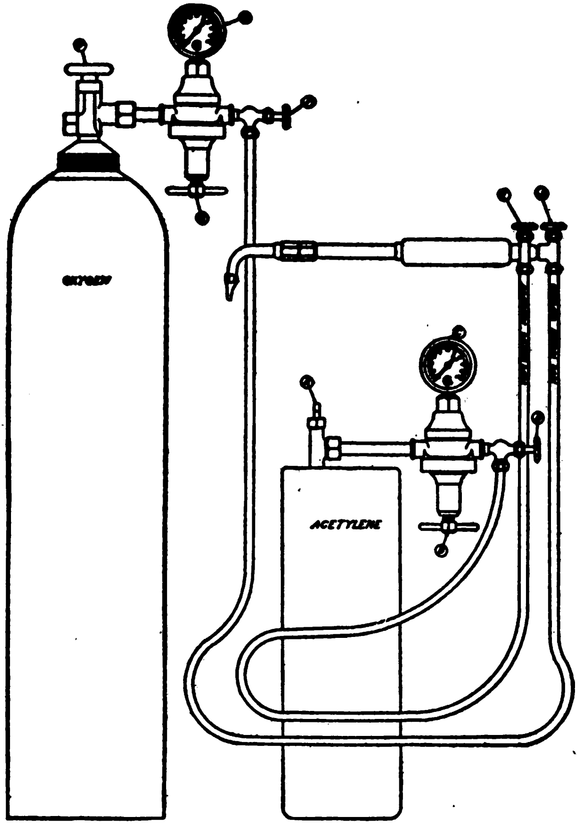

Figure 74.—Regulating the Acetylene and Oxygen

shows two white cones. Figure 75 shows the appearance at this stage for each number of nozzle. Open

the oxygen torch valve until the large cone in Figure 75 comes down to the size shown on Figure 76, which is correct for a neutral flame. This process may be repeated to advantage by again turning on more acetylene and reducing it once more until you have the desired flame.

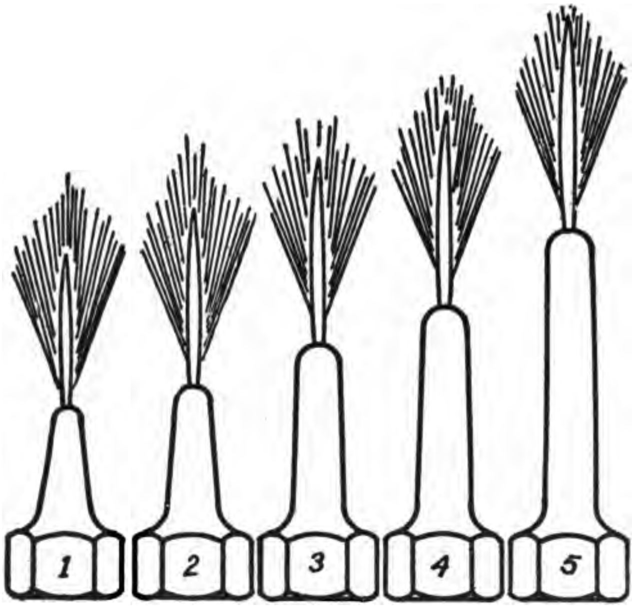

Figure 75

The flame is now in proper condition for welding steel, iron and cast iron. Aluminum requires an excess of acetylene. The proper regulation of the flame should be continually attended to inasmuch as an excess of acetylene carbonizes the metal and an excess of oxygen burns it. If the weld has a fine

spongy appearance it is certain evidence that the flame is oxidizing the metal or burning and weakening it.

Always unscrew the handle on the oxygen regulator and on the acetylene regulator until the pressure is entirely removed from the diaphragm before

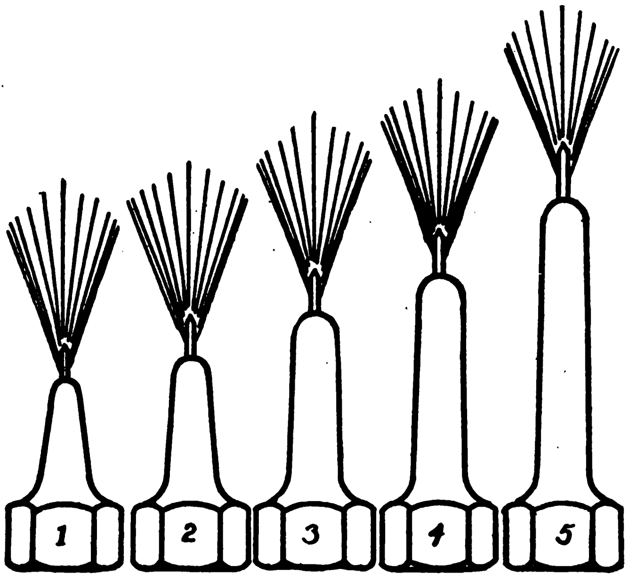

Figure 76

opening the tanks, as the diaphragms are made of thin copper and soldered into place, the enormous pressure striking them suddenly will cause them to leak. Also in turning on or opening the tanks, always open them very slowly, so that the hand creeps around, as by opening them suddenly you are liable to injure the hollow spring in the gauge. Next

see that there is no leak between the tanks and the regulators. On the oxygen this may be ascertained by holding a lighted cigar close to the fittings, if it burns brightly there is a leak. Never use a light near the acetylene tank, but as the acetylene gas has an odor, you will be able to detect a leak very readily. You are now ready to screw on your welding tip, select the size tip necessary for the thickness of metal you are going to weld. Now turn the pressure on the acetylene regulator by screwing in and light the torch. See that you have enough pressure on the acetylene to blow the flame away from the end of the tip about one-eighth of an inch, showing one-eighth of an inch of clear space between the tip and the luminous flame. Next turn on enough oxygen pressure to overcome the acetylene and draw it down to a clear white welding cone; you are now ready to weld.

Welding Procedure.—Careful attention must be paid to the preparation of the parts to be welded. In the case of wrought iron and steel, the pieces to be welded must generally be chamfered off at an angle of 45 degrees, so as to enable the flame to come into direct contact with the whole of the surfaces to be united, then direct flame to center, holding torch perpendicular to lowest point.

The groove formed by the chamfered edges is filled by fusing in steel or iron wire while maintaining the bottom and sides in a state of fusion. The wire must not be fused in unless the bottom and sides of the groove are also in a state of fusion. This is the secret of successful welding.

Commence at the nearest point and work "away from you." The torch should be maintained at a

uniform distance, having cone of flame just touching work (the greatest heat is just on the point of the cone), and advance slowly and regularly and work around in a circle, when finishing.

Where the maximum strength obtainable is required, it is desirable, if possible to weld from both sides. This is particularly advantageous with heavy work, as it allows a much smaller nozzle to be used than if all work is handled from the one side.

If small round holes appear in iron and steel they can be filled by heating the metal around the hole to a white heat and then filling by two or three quick passages.

The torch must never be held still for a moment, but must always have a circular or oscillating movement around and across the point of welding. The welding rod must be held down in the joint so that it is at all times touching the metal being welded and must never be applied in drops from the end of the rod. After enough has been melted from the rod it may be drawn back a short ways out of the direct welding flame, but not taken from the work while the new metal is worked into the joint.

In welding fractured castings, it is not always necessary to chamfer the edges of the pieces to be united. It is, however, necessary that the material should be run right through. This can be done by means of the torch.

In dealing with complicated castings, such as auto cylinders, precaution has to be taken to prevent new fractures developing from expansion and contraction, owing to internal strains set up by the intensity of the local heat.

Stopping the Installation.—This implies two con-

ditions, (1) the temporary extinguishing of the torch to enable the welder to examine the portion of the work already executed, to adjust the work or prepare another weld, or (2), a definite stoppage for a longer period, as for example, between the hours of work.

In the first case the temporary closing of the oxygen can be effected by means of the valve at the outlet of the reducing valve, while the acetylene may be cut off by the cock on the torch, on the hydraulic valve, or cylinder.

For a longer stoppage, the torch should be first extinguished, the cylinder valves should then be closed or the admission valve to the hydraulic valve if this form is being used. This done, the cocks on the torch are to be re-opened to allow the escape of the excess gas stored by pressure in the various parts. Finally, the regulating screw of the reducing valve is turned out until free. Also notice whether the gauge reads zero.

General Advice.—The welder should always use a blowpipe (or a head-piece in the case of blowpipes of variable delivery) corresponding to the kind and thickness of the metal to be welded.

Increasing the power of the blowpipe by increasing the pressure of the oxygen is not good practice, and would not be indulged in by a conscientious welder.

Each type of blowpipe and each number of the same type corresponds for normal working to a pressure which cannot be increased without increasing the proportion of oxygen and oxidizing the welds. This pressure is generally given by the makers in their catalogues; it should be summarized in a table fixed near the welding benches. Endeavor to lower

the working pressure of oxygen indicated, but never raise it.

The welder should not blindly depend on the reading of the reducing gauge for obtaining the required pressure of oxygen; sometimes the pointer is in advance or behind; in case of doubt it is necessary to make a comparison with another reducing valve using the same blowpipe.

An experienced welder may not consult the reducing gauge for obtaining the required pressure of oxygen, but regulates by the flame, keeping the pressure as low as possible for a normal white jet, without too great a rigidity, and without any return to the interior.

An autogenous welding installation is perfectly safe, and should not cause any accident if it is installed, erected, and worked according to the conditions we have indicated. All ignition by leakage, blunders, or faulty manipulation produce no serious danger if one immediately closes the valve of the oxygen cylinder, and the cock for the admission of the acetylene to the welding place. Beware of oxygen leakages, apparently of no consequence, which can provoke a rapid fire, for example, of the clothes, by a simple spark coming from the weld.

Be sure the welding flame is neutral.

Be sure the part to be welded is set up properly. A poor set up may spoil the best weld for practical use.

Proper heat treatment before and after welding is as important as good welding, when intricate castings, such as cylinders and crank cases are being repaired.

Avoid hard spots in cast iron welds by preheating

before, and annealing afterward. Take care in using sufficient heat in welding and do not make the union between casting and filling material too sharp and defined.

Do not allow drops of metal to fall on partially molten metal.

Use the best grade of filling material. The best is none too good when all the expense of the repair may be lost by a weak weld.

When preheating aluminum castings for welding, do not attempt to heat in one place only. Keep the burner moving to spread the heat uniformly.

In welding steel be careful that the metal above the weld does not weld together and leave a space that is not welded. A "V" shaped groove will prevent this.

Handling Work of Varying Thickness.—Autogenous welding is not easily applied to the joining of pieces varying appreciably in thickness. This is due to the fact that the melting of the two edges is not equal and does not take place at the same time, since the torch is too powerful for the thin piece or too weak for the thick piece.

This difficulty, however, can be overcome by using two torches, the one raising the thick piece to red heat and the other of less power for the thin plate. Another method consists of laying a heavy piece of heat conducting metal, such as red copper, under the thin piece so as to carry off the excess heat.

Thick Pieces.—When the thickness to be welded is over ¾ inch it is advisable, where possible, to bevel both sides and weld from both sides. If the joint warrants it, two torches may be used, one on each side. For very thick work the welding rod metal

may be added in two successive layers, being careful to secure fusion of each layer. Another method is to work from the bottom of the groove in steps.

Thin Pieces.—The welding of thin pieces requires a certain amount of skill, and beginners require a great deal of practice before they are able to do it well.

The welding of thin plates under $\frac{1}{16}$ inch is particularly difficult on account of the separation or warping produced by expansion; also the least excess of heat tends to produce holes which are difficult to avoid when the metal is very thin.

The welder should carefully watch that the edges to be welded do not overlap each other; if one can bend them up a small height, $\frac{1}{16}$ inch for example, the execution of the weld becomes much easier; the metal bent over serves as a welding rod, and, after welding, the line of welding is equalized with a hammer.

Cleaning.—The edges to be welded, and their immediate neighborhood, that is, where fusion takes place, should be cleaned until the metal is wholly free from foreign matter. According to the state of the surfaces to be cleaned, this may be done with a grind stone, file, scraper or simply with emery cloth. The rust and all particles that are detached from the cleaned surfaces must be removed from the line of welding, and especially from the bottom of the bevel. In the absence of mechanical cleaning, chemical agents termed fluxes may be used. These fluxes generally work well, but it is advisable to precede their use with mechanical cleaning also.

CHAPTER XI

METAL WELDING PRACTICE

Fluxes.—It is not always possible to incorporate in the welding metal itself those elements most favorable for combating the oxidation of the welds, and the loss of certain constituents, etc. Further, certain products, notably fluxes, are employed previous to fusion of the metal, and having a different object than the welding metal; it is these considerations which justify the use of powders, liquids, or pastes.

The powders and products used do not do away with the necessity for a special welding metal; they are, in the majority of cases, cleaning and deoxidizing fluxes destined to prepare the edges of the weld and eliminate, by way of combination, the oxide which is formed during welding.

These compositions require equally great care in the preparation. Although their use in greater or less quantity has generally no effect on the composition of the metal, their defective manufacture tends to produce inconveniences when they are used, and in consequence the bad execution of the weld. The cleaning fluxes for the various metals are most convenient to use when in the form of a powder.

The flux is used by plunging the extremity of the welding rod into the box or bottle, the rod having previously been heated, but not to excess. Avoid throwing the powder into the molten metal while executing the weld; the supply from the welding rod is always sufficient.

The usual composition of fluxes for the various metals is as follows:

Cast Iron.—Equal parts of carbonate and bicarbonate of soda to which is added 10 to 15 per cent of borax and 5 per cent of precipitated silica.

Ordinary table salt may also be used.

Flux should not be used unless metal does not run freely, and then only sparingly. Too much flux causes iron to harden so that it cannot be drilled or machined.

Steel.—Borax, boracic acid, sodium chloride (salt). Do not use flux on steel unless metal will not run.

Mild Steel—Wrought Iron.—Same as above, used sparingly or not at all.

Copper, Brass and Bronze.—Same as above. When used for brass make a paste with a little water.

Aluminum.—

Lithium chloride	15 per cent.
Potassium	45 per cent.
Sodium	30 per cent.
Potassium flouride	7 per cent.
Bisulphate of Potassium	3 per cent.

Plain borax may also be used for aluminum.

Welding Rods.—These are rods made from a metal practically the same in composition as that to be welded. They are made in sizes adapted to the nature of the welding. For very light work the diameter of the rod may be as small as $\frac{1}{16}$ inch and for heavier work this diameter increases up to ½ inch or more, being usually about ½ the thickness of the work.

Their composition, of course, depends on the metal to be welded, for example, aluminum rods are made from the purest aluminum obtainable; for iron or mild steel the rod is of soft iron; for copper it is of phosphor copper with traces of aluminum; for cast iron

the rod is cast iron, etc. These rods may be purchased from any of the welding apparatus manufacturers.

Steel Welding.—The welding of steel presents less difficulty to the operator than any other metal to be welded. It runs together very readily and in this connection it must be borne in mind that all sections of steel should be beveled so that welding can begin at the bottom or in the center of thick pieces. Otherwise the steel, which as noted, runs together, will weld only on the surface. Flux is not really necessary with steel.

The rod for steel should be the same grade or better grade than the pieces to be welded. In thin sheets, strips may be cut off and used as filling rods, or wire may be twisted together to make the rod.

For $\frac{1}{16}$ inch or under put the edges together and melt through, moving your welding flame in small circles to flow the edges together, add new metal from a welding wire where necessary.

For heavier steel grind the edges so that you will have a 45° V, melt the edges together seeing that the bottom of the V is hot enough to unite thoroughly, then add enough metal from your steel welding rod to fill the V level with the rest of the sheet.

When welding on heavy metal it is economy to preheat the sheet or casting welded with a natural or artificial gas torch, charcoal, or coke, as the work can be done much faster and with a great saving of oxygen and acetylene and you will make a better and stronger weld. In seam welding where the metal is thin and liable to warp, start welding about 6 inches from the end, leaving the far end open about ⅛ inch to the foot of the seam, weld across the sheet and return and finish the six inches starting on the inside and

working towards the end. Where this method is not practicable, stick the sheet every six or eight inches and begin welding in the center and work to the ends. Select a tip large enough to melt the metal readily and finish your weld in one spot and move on, as it is very bad for a weld on any metal to keep the flame in one place too long. You are liable to burn the metal and make a weak, hard weld.

Steel of 1/8 inch and less in thickness can be welded without the addition of any metal from a rod. When adding material to heavier work do not commence until the part to be welded is flowing freely, and when in this condition add metal from the rod, being sure that the rod is touching the work at all times.

Hold the torch so that the flame strikes the end of the rod and the work at the same time. If a foam gathers on the top of the weld while welding, throw the flame a little further away from the work and keep trying this until the metal flows freely without this foam gathering. Be sure about this as it is very important. It may be necessary to keep the flame off for about ten seconds.

In welding a crack in the middle of a heavy steel sheet, prepare the crack by chamfering the metal on each side of the same at an angle of 45 degrees to the bottom, then, as previously directed, apply the welding torch to the metal beyond the end of the crack until it is expanded enough to open the crack perceptibly, and make the weld while the metal is in this condition, and usually it will be found that the expansion has been sufficient to care for the contraction in the weld when cooling.

When the weld is completed, do not forget to pass

the torch over it and the surrounding metal, as previously instructed.

Cast Iron Welding.—In welding cast iron preheating is essential to insure a soft weld free from blow holes. For auto cylinders, crank cases, and all similar castings, it is imperative to preheat the casting slowly, and after making the weld, cool slowly either by turning the preheating flames down gradually, or if charcoal is used, cover the casting to keep the air off and let the fire die out, or by removing the casting from the fire and when hot place in slack lime or fine ashes. It is also well to heat the lime or ashes before placing the casting in it.

It is necessary to use a good flux in cast iron welding, one that will throw off impurities and make the metal flow freely. Also select your cast iron rods with care, using only soft iron high in silicon.

If the piece to be welded is of such form that it will crack in cooling, an engine or pump cylinder, it should be preheated, but not sufficiently to warp the metal, no part to be brought to a dark red except at the welding point. Charcoal is a good material to preheat with, as the heat is uniform.

There are many pieces of cast iron that can be welded without preheating, but where it is convenient to do so, it is advisable to preheat, as it saves the oxygen and acetylene gases.

If the metal is more than ¼ inch in thickness, the edges should be champfered to about 45 degrees. In the heavier welds, it is desirable to leave three slight points of contact to assist in adjusting and holding the broken parts in their exact position while welding.

To make the weld, the torch should be passed for some distance around the fracture and then directed

onto the fracture until the metal begins to run. Then add cast iron from the cast iron welding rod, but use flux only if the metal does not flow well. Never attempt to re-weld pieces that have already been welded and broken without cutting away all the old metal. To weld cast iron to steel, use cast iron rods and heat the steel to the melting point first, as cast iron melts at a lower temperature. Use but very little flux.

To Weld an Engine or Pump Cylinder.—First take a diamond point chisel and chip all around the fracture until almost through, then have a forge large enough to start a fire all around the cylinder, not a large fire, but a fair size, of charcoal. Keep this fire going for at least four hours, but do not let it get any larger and be sure to have the piston opening of the cylinder down, and the fire well in under so that the heat will go up through the dome. This will distribute the heat evenly all through the castings. Have asbestos paper and keep the piece covered all the time from start to finish, leaving an opening just large enough to weld with. At the end of four hours the piece should be ready to start welding. At this time put a little charcoal all around the fire. Then lay the engine cylinder down as level as possible with the fracture up. It would be well to have an assistant ready as soon as the weld is started. In starting the weld, start at the back end of the fracture, if there is a back part. The piece will start to expand as soon as the welding begins. If this was not done it would crack before the weld was finished. So if there is an opening start at the back end and finish welding at the opening. If it is a round fracture and a piece broken out, start welding anywhere. Play the torch all around the fracture first and then bring the small

white cube, just the point of it, on the end where it is intended to start, at the same time have cast iron welding stick resting where the weld is to begin; then have the white cube spoken of strike the piece to be welded and the welding stick at the same time. It may be necessary, if the cylinder is badly burned, when it is nearly at a melting point to push gently on the welding rod. This is to lift up the iron and let the heat get under it. Do this carefully so as not to get too much weight on the welding rod, or it will push it through and make a hole. Keep the torch right close all the time. As soon as the weld is finished draw the fire closely together. Have your assistant ready with tongs or something suitable, and turn the weld right over into the fire so that it will get the full heat of the fire. If it is a long weld, when about one inch is finished place a piece of asbestos paper over it to keep the cold air from striking it. Keep doing this as fast as you proceed until the piece is finished. Then cover it up very carefully, so that no air can strike it, and under no circumstances uncover or disturb it until the next day. This will keep it from cracking generally, but sometimes it will crack after the greatest precautions are taken. The only remedy is to chip it out again and begin all over.

Malleable Iron Welding.—Parts of malleable iron are handled in much the same manner as cast iron parts in preparation for welding. It is usual to strengthen the weld as much as possible by building up from the rods. Nickel steel may be used for filling in the bottom of the crack or bevel, cast iron being placed on top. Wherever the metal is to be drilled or otherwise worked there must be no junction of the new metal with the old. If it is necessary to avoid

this junction coming at a place that must be worked or machined, a greater amount of old metal must first be cut away and the whole space filled from the rod.

As a reinforcement it may be necessary to strap the parts with wrought iron or steel bands welded to the body of the casting. Bear in mind that heating malleable iron turns it to ordinary cast iron at that point.

Malleable iron is the most refractory metal that the welder has to contend with. It has been found that Swedish iron with a small copper wire twisted around it is the best for some malleable castings, while it will not work at all on others. When this fails, use manganese bronze and where possible reinforce by leaving the welded joint heavier than the rest of the casting. For a flux use as on cast iron, but do not heat the malleable iron as hot as the cast iron, merely hot enough to coat freely with the bronze, then fill in.

Aluminum Welding.—The welding of aluminum requires considerable skill and experience before successful work can be expected on intricate parts. The manner of making the weld is slightly different than is used with welding of cast iron, due to the fact that when aluminum is heated, an oxide film is formed, which prevents the metal running together and forming a suitable weld. To overcome this, the aluminum filling rods must be inserted into the molten aluminum, which is being welded, and moved about rapidly, something similar to puddling, in order to break up this oxide film and allow the aluminum to run together. A flux has also proven to be of advantage in this connection, where before, practically all of this work was done without the use of a flux.

While aluminum melts at a lower point than any of

the other metals mentioned, it is necessary to have a high concentrated heat to melt it at the point to be welded and not get it too soft on each side of the weld. As aluminum does not show heat as other metals do, it is necessary to go by the sense of touch. Use a spatula or spoon made by flattening the end of a piece of steel, scrape the casting where you are heating it until it softens, and add new metal from your cast welding rod, always making sure that your metal underneath is soft enough to unite with the metal you are adding to it. Use your steel spoon freely and work the edges together. When you have finished the weld scrape off the surplus aluminum with the spoon.

A larger tip is necessary for welding a section of aluminum than would be required for the same section of steel or cast iron. This is due to the fact that aluminum conducts heat very rapidly. With the proper size tip in use, it is necessary to melt a considerable portion of aluminum, which is being held up in shape by the fire clay form. Now the extra metal can be added from the filling rod and stirred or puddled with this rod to break the oxide film, which forms when aluminum is melted.

A flux, for use in this connection, will be found very valuable for breaking up this film. In fact, by using this flux, bosses can readily be built up at any desired point. This is something that could not be done before a flux for welding aluminum came into general use.

All precautions should be taken to have work securely fastened, or harnessed. For instance, in the welding of a hole in the side of a crank case, it is customary to clamp a shaft, which approximates the size

of the bearings (less, of course, the cast metal bearings, which would melt out), into the crank case bearing supports, in order to insure perfect alignment of the bearings. Angle irons are bolted to the flanges where connection is made to the other half of the crank case in order to insure perfect alignment of this part.

It is good practice to place a sheet of paper on the inside of the case next to the crack to be welded. This paper prevents the fire clay from getting into the crack. Upon this is placed fire clay in plastic condition, which is held in place by means of asbestos fibre. This makes a light backing or mould for the case and can be easily handled without fear of the mould or core being so heavy as to break down the case when heated for welding. This mould should be large enough to cover sufficient area around the crack so that the aluminum will not break down.

Aluminum to be welded should be well scraped. If the weld is more than 1/4 inch in thickness, it is advisable to chamfer the same. Aluminum should always be preheated and kept covered, except where the weld is being made, and then quickly covered with asbestos paper until it is well cooled.

To make a good weld in aluminum, heat the whole piece slowly, to about 300° or 400° short of the melting point, then cover the pieces with asbestos paper, or by other means, leaving an opening where the weld is to be made, keeping the whole piece hot until the weld is completed. After the weld is finished, cover the piece completely to protect it against drafts, and so that it will cool very slowly, to prevent shrinkage cracks.

It will be noticed when putting the welding flame on the aluminum at the fracture, that the aluminum does not run together. An iron rod, of which the

point is flattened and bent about ¾ of an inch, like a small poker, and pointed, should be used to puddle the aluminum, and this rod should be wiped frequently, so that it will not become coated with aluminum. A jar should be provided and filled with a saturated solution of water and table salt, and the mixing rod should be dipped into the same occasionally while welding. It is better to have three of these puddling irons and keep them in the salt solution while using. In this way you always have cool ones ready. Great care should be taken not to let the rod reach a red heat, as this would cause oxide of iron to form on the rod, and this mixing with molten aluminum would make a defective weld. The salt remaining on the rod, when coming into contact with molten aluminum, forms a very thin film, excluding to a certain extent oxidation by oxygen contained in the air.

Aluminum parts must always be preheated and handled in a similar manner as automobile cylinders, as outlined before, with the exception that aluminum, of course, should not be heated to such a high temperature, on account of the fact that within 122° Fahr. of the melting point, the metal is very brittle and without strength. It is customary to heat up these cases thoroughly until they will melt half and half solder in wire form. This temperature is about right to prevent cracking occurring on account of expansion and contraction and at the same time, the aluminum will possess sufficient strength so that with ordinary handling, no trouble is experienced with alignment or failure of the part.

Great care should be used in preheating crank cases, transmission cases, etc., to get them hot enough and yet not overheat them and warp them out of shape.

It will be found that clamping liners on a case will greatly aid in preventing warping.

Aluminum Crankcase Welding.—To weld aluminum properly first get a jar and put a handful of salt in it. Then fill it up with water. Next make some wrought iron pokers about 15 inches long with a bend of 5/8 inch. Have the point sharpened about like a lead pencil. Throw a ring on the other end with which to handle, to make it easier to hold. These are the things that will be needed first. Take the aluminum casting, put it in a large forge or on some suitable table, and set it up on bricks. Then build a small charcoal fire all around it. Keep this fire going for about an hour and a half.

At the end of this time cover the piece to be welded with asbestos paper, leaving an opening large enough to get at the fracture. Then take one of the pokers in the right hand and hold the torch in the left hand. Apply the flame on the part of the fracture that you are going to weld and keep poking with the poker until it gets soft. When it begins to get soft, you can puddle it until you get almost through on the other side. Keep doing this all the way along until you get the fracture welded. Never start welding at the opening, always start at the back end and work toward the opening, finishing there. It would probably be a little rough, but you can play the flame on it and keep drawing the poker over it and keep smoothing it down to your own satisfaction. Of course add metal from the aluminum welding stick from time to time to make the weld higher than the rest of the casting. It can be filed down to size afterwards. Then turn it over quickly and do the same thing on the inside as on the outside. Be sure not to uncover

the piece after you begin to weld, or a cold draft may strike it and it will break again. Do not cover it with asbestos paper before starting to weld, or the piece may melt on the parts nearest to the fire. Do not uncover the piece under any circumstances until the next day.

We would strongly advise clamping some cast iron straight edges on the face of the castings to keep them in line. These straight edges should be at least one inch thick and one and a half inches wide, and be long enough to extend the entire length of the crankcase face.

Add the new aluminum from rods. These rods can stand in a salt solution, or be dipped occasionally.

There are many pieces of aluminum that can be welded without preheating, as will soon be learned by the experience of the operator. Lugs or projecting pieces broken completely off do not require to be preheated. Pieces broken out and entirely lost can in nearly all cases be fitted in, or built up with little difficulty.

Welding of Brass, Copper and Bronze.—To weld copper use the same kind of a flame as for aluminum, but a much larger tip and flame must be employed for pieces of equal size because of the greater heat radiating power of copper. Preheating is necessary with large pieces of copper, otherwise the heat of the torch would be absorbed by radiation and but little left for fusion of the metal.

Copper will weld at about 1929° Fahr., consequently the flame need not be of so high a temperature as for steel and it must not be concentrated on so small a surface, but on account of the radiation the total

quantity of heat will be even greater. Flux is not really needed with copper.

In brass welding keep the point of the dull white flame about touching the weld, according to the thickness of the piece, so that the heat will not be sufficient to burn the copper, which is in the brass, and also consume the zinc. If a white smoke should be created, remove the flame, as this indicates that too much heat is being used. Use flux as it will assist greatly in making the weld. Use flux as a paste by mixing it with water. Dip welding rod in the paste and apply it quickly to the work.

The preparation of brass and bronze castings for welding is similar to that for cast iron castings. The fracture must be caped out so that the welding can start at the center, the groove being filled with metal melted from the filling rod.

The filling rod should be of approximately the same mixture as the part to be welded. Brass should never be used as filling material for bronze castings, and a strong weld expected. Powdered borax or boric acid may be used as a flux. A mixture of one-half borax and one-half boracic acid gives good results.

In welding brass or bronze the work is carried out as for welding cast iron. The metal surrounding the groove is melted and the filling material added, drop by drop, as it is melted from the rod. Be sure the metal of the casting is in a molten condition, otherwise an imperfect weld will result. Brass welds can be easily spoiled by burning the zinc out of the composition. Care should be taken not to heat beyond the melting point. Flux should be used freely. If the welded portion has been burned, it will be exceedingly porous. Make your weld as quickly as pos-

sible, as holding the welding flame on the metal too long burns it and makes a weak, porous weld.

In welding brass use brass wire spelter which flows more freely than cast rods. For copper use a pure copper rod, or if this is not to be had, soft copper wire will do very well for a substitute.

In welding bronze where the surface is to be polished and it is necessary to keep the same color, use rods of the same material.

CHAPTER XII

OXY-ACETYLENE CUTTING

Oxy-Acetylene Cutting Apparatus.—The process of rapidly cutting iron and steel with the blowpipe and a jet of oxygen has been considerably developed, especially in workshops using autogenous welding, since the necessary material, save the blowpipe, is the same in the two cases. The addition of one or more cutting blowpipes to the welding installation is, in many cases, of great value.

Cutting blowpipes consist of an arrangement for giving a heating flame, generally that which is adopted in welding blowpipes, and to which is joined in a permanent manner a second arrangement for bringing the cutting oxygen, its regulation and its projection on the metal. The chief characteristics of a good cutting blowpipe are that these arrangements should be so combined that it is hardly possible for them to get out of order, and of easy management.

However, the construction and regulation of cutting blowpipes are not so simple as this definition might lead one to believe. The form and arrangement of the various details have considerable influence not only on the good working of the blowpipe during the operation, but also on the cleanness of the cut and, above all, on the consumption of oxygen.

In construction work the line of cut should be as clean as possible. The use of a machine holding the blowpipe absolutely rigid, always at the same distance, and allowing a very regular advancement ac-

cording to the cutting, is indispensable, especially for great thicknesses.

Portable Cutting Apparatus.—Manufacturers of oxy-acetylene welding equipments, especially of the portable and semi-portable type, as a rule so design their apparatus, that by a few simple changes, it may be converted from a welding to a cutting device in a few minutes.

Cutting, with this apparatus, offers practically as large a field as does welding. The saving in time is a great advantage, and besides, it is possible to cut with the oxy-acetylene blaze where it would be impossible to work with the steel saw or cold chisel.

The process is used to a large extent by railroads for clearing up wrecks and for construction work on steel coaches. It has practically revolutionized the methods of constructing and wrecking.

The metal to be cut is heated with a torch until almost white hot. Then the extra cutting jet of pure oxygen is introduced, which, upon striking the heated metal separates it with a smooth narrow cut. The surrounding metal is uninjured. It is not necessary to go through any preparation for this work, and cutting can be done in any place that the operator can reach with the torch and hose lines. Metal of practically any thickness can be cut and any desired form can be followed.

Multiple Jet Cutting Torch.—The head or tip of this torch is so constructed that it has six separate and distinct heating jets or flames, evenly divided and of exactly the same degrees of heat and proportion, arranged in a circle. The jets or flames are all controlled by a needle valve for acetylene and another needle valve for oxygen. The extra cutting

jet for the oxygen supply is arranged in the center of these six heating jets, thus allowing the cutting flame to act in the hottest spot at all times. It is equipped with a two wheel carriage which can be adjusted so that the heating flame is at all times the proper distance from the work.

Lighting and Operation.—First turn on the acetylene and light it, then turn on enough more acetylene until you have a good strong flame. Next turn on oxygen slightly—you will now have a long light flame. Keep turning on oxygen slowly until the long white flame is drawn to six small flames about one-quarter inch long. Next turn on the acteylene until the flame lengthens out to a long white flame again, then turn on the oxygen again slowly until you get the six small white flames again. Continue to do this until you get full heating capacity. Next hold the flame on the work where you are to begin cutting; as soon as the metal gets red, pull back the lever on the handle. This allows the catch to fall into the slot prepared for it, and the cutting begins immediately.

It is well while cutting to dip the head of the torch in water frequently until it gets quite cold, for the reason that if the head and tip of the torch get quite hot the gases are expanded to an explosive point, when it explodes in the chamber around the inside tip, concentrating the flame direct on the inner tip and melting it. This can be obviated by turning off the gases frequently and cooling off the head and tip in water as explained.

Befort starting attach the fixture with the two wheels at the end of the tip, tighten it with the screw in the center. This should be so adjusted that the points of the six small white flames will just touch

the work to be cut. The tremendous volume of heat from the cutting torch will melt any metal, so keep the head of the torch out of holes or pockets if possible; if not, dip frequently in water as explained in foregoing.

A combination welding and cutting equipment is made which can be instantly converted from a welding to a cutting apparatus, by simply removing the welding nozzle and inserting the cutting nozzle in its place. Following are the instructions for lighting and operating this cutting torch. These instructions apply particularly to the cutting of steel.

Remove the welding tip and screw in the cutting tip; turn on sufficient acetylene to blow away from the end of the tip, the same as in lighting a welding torch, then turn on enough oxygen to overcome the acetylene and draw down to a clear white cone. Hold the end of the tip about one-half inch away from the metal to be cut and move the torch forward as fast as you can do so steadily and without jerking, as by jerking it forward the jet of oxygen will strike cold metal and stop cutting. Three-eighths to one-half inch plate should be cut at the rate of one foot per minute. Insufficient pressure on either gas or oxygen or striking the end of the tip against the metal will cause the flame to burn back in the tip. If the flame burns back in the tip shut off the gas at once to prevent burning out the thin central oxygen tube. When this tube is spoiled, unscrew the check in the back end of the tip, draw out the old tube and replace it with a new one, making sure that the tube is tight at both ends. If the holes become clogged with particles of steel, clean them out with a small reamer or drill, but do not enlarge them.

Operating Cutters.—After connecting the apparatus and seeing that everything is absolutely tight, close both valves on the cutting torch and turn on about 20 lbs. pressure of oxygen, still leaving the oxygen valve on the cutting torch closed.

Then turn on the acetylene and light at the tip. Turn on until the flame leaves the tip slightly. Then turn on the oxygen at the handle of the torch, not all the way on, but just enough to produce a neutral flame as for welding. Hold the torch at the edge of the metal to be cut, using wheel carriage to guide the torch if there is one, otherwise holding the nozzle about one-half inch from the work. As soon as the metal gets hot enough to melt, or nearly so, open the cutting jet full and proceed in the direction you wish to cut.

CHAPTER XIII

OXYGEN PROCESS FOR REMOVAL OF CARBON

Until recently the methods used for removing carbon deposits from gas engine cylinders were very impractical and unsatisfactory. The job meant dismantling the motor, tearing out all parts, and scraping the pistons and cylinder walls by hand.

The work was never done thoroughly. It required hours of time to do it, and then there was always the danger of injuring the inside of the cylinders.

These methods have been to a large extent superseded by the use of oxygen under pressure. The various devices that are being manufactured are known as carbon removers, decarbonizers, etc., and large numbers of them are in use in the automobile and gasoline traction motor industry.

Outfit.—The oxygen carbon cleaner consists of a high pressure oxygen cylinder with automatic reducing valve, usually constructed on the diaphragm principle, thus assuring positive regulation of pressure. This valve is fitted with a pressure gauge, rubber hose, decarbonizing torch with shut off and flexible tube for insertion into the chamber from which the carbon is to be removed.

There should also be an asbestos swab for swabbing out the inside of the cylinder or other chamber with kerosene previous to starting the operation. The action consists in simply burning the carbon to a fine dust in the presence of the stream of oxygen, this dust being then blown out.

Operation.—The following are instructions for operating the cleaner:—

(1) Close valve in gasoline supply line and start the motor, letting it run until the gasoline is exhausted.

(2) If the cylinders be T or L head, remove either the inlet or the exhaust valve cap, or a spark plug if the cap is tight. If the cylinders have overhead valves, remove a spark plug. If any spark plug is then remaining in the cylinder it should be removed and an old one or an iron pipe plug substituted.

(3) Raise the piston of the cylinder first to be cleaned to the top of the compression stroke and continue this from cylinder to cylinder as the work progresses.

(4) In motors where carbon has been burned hard, the cylinder interior should then be swabbed with kerosene before proceeding. Work the swab, saturated with kerosene, around the inside of the cylinder until all the carbon has been moistened with the oil. This same swab may be used to ignite the gas in the cylinder in place of using a match or taper.

(5) Make all connections to the oxygen cylinder.

(6) Insert the torch nozzle in the cylinder, open the torch valve gradually and regulate to about two lbs. pressure. Manipulate the nozzle inside the cylinder and light a match or other flame at the opening so that the carbon starts to burn. Cover the various points within the cylinder and when there is no further burning the carbon has been removed. The regulating and oxygen tank valves are operated in exactly the same way as for welding as previously explained.

It should be carefully noted that when the piston is

up, ready to start the operation, both valves must be closed. There will be a considerable display of sparks while this operation is taking place, but they will not set fire to the grease and oil. Care should be used to see that no gasoline is about.

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